

DOCUMENT RESUME

ED 141 138

SE 022 649

TITLE Earth Science Supplement to the Syllabus, Part 2, Topics 5-8, 1970 Edition. 1974 Reprint.

INSTITUTION New York State Education Dept., Albany. Bureau of Secondary Curriculum Development.; State Univ. of New York, Albany.

PUB DATE 74

NOTE 111p.; For related documents, see SE 022 648, ED 064 102 and ED 046 749; Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF-\$0.83 Plus Postage. HC Not Available from EDRS.

DESCRIPTORS *Earth Science; Environmental Education; *Instructional Materials; Laboratory Procedures; Physical Sciences; *Science Activities; Science Education; Secondary Education; *Secondary School Science; *Teaching Guides

ABSTRACT

This document contains investigation topics 5-8 in the earth science course developed by the University of the State of New York for secondary schools. Topics include energy in earth processes, insulation and the earth's surface, energy exchanges in the atmosphere, moisture and energy budgets, and environmental change. Each topic is preceded by the Investigations-Understandings Matrix which illustrates the relationship of the investigation to the major understandings, and is also used to relate multimedia materials to the topic. The laboratory investigations are presented in two forms: teacher laboratory guide sheets and student laboratory guide sheets, which may be duplicated to provide structured procedures for the students. The level of difficulty of each investigation is indicated on the teacher guide sheet as easy, challenging, or difficult. Although these activities are in a supplement, they are considered essential to the core of the course. (SL)

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SE 022649

t o p i c v

What Is the Role of Energy in Earth Processes?

Time Emphasis: 7 days

INVESTIGATION		A-1a	A-2a	B-1a	B-1b	C-1a	LTI - #5	FE - #5											
Time Emphasis (Periods)		2	1½	1½	1	2	LTI - #5	FE - #5											
TOPIC OUTLINE	A. Electromagnetic energy and energy transfer																		
	A-1 Electromagnetic energy																		
	A-1.1 Properties																		
		A-1.11																	
		A-1.12																	
		A-1.13																	
		A-1.14																	
		A-1.21																	
		A-1.22																	
		A-1.31																	
	A-1.2 Solar energy																		
	A-1.3 Earth energy																		
	A-2 Energy transfer																		
		A-2.11																	
		A-2.21																	
		A-2.22																	
		A-2.31																	
	A-2.2 Convection																		
	A-2.3 Radiation																		
	B. Energy transformation																		
	B-1 Transformation in earth processes																		
		B-1.11																	
		B-1.12																	
		B-1.13																	
		B-1.21																	
		B-1.31																	
		B-1.32																	
		B-1.41																	
	B-1.2 Movement of water																		
	B-1.3 Wavelength absorption and radiation																		
	B-1.4 Friction																		
	C. Energy relationships in earth processes																		
C-1 Conservation of energy																			
	C-1.11																		
	C-1.12																		
	C-1.13																		
	C-1.14																		
	C-1.15																		
	C-1.16																		
C-1.1 Closed system																			
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIQ-1																	
	Measurement Skill	PIQ-2																	
	Creating Models	PIQ-3																	
	Analysis of Error	PIQ-4																	
	Data Analysis	PIQ-5																	
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Electromagnetic Spectrum																
			Heat Transfer																
			Changes in State																
			Energy Absorption																
			Specific Heat																
			Stream, Pond, or Lake Temperature																
			Beach																

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V-A-1a: ELECTROMAGNETIC SPECTRUM

QUESTION:

What are the properties of electromagnetic energy?

MATERIALS:

Spectrum kit or piece of diffraction grating, pieces of red and blue glass or cellophane, NaCl, (optional: other salts such as SrCl_2 , LiCl , BaCl_2 , CuSO_4 , KCl) heat source, gas discharge tubes (if available), colored pencils.

SUGGESTED APPROACH:

1. Have the students use a spectroscope to study the visible energy from the sun.
2. Aim the slit toward the bright sky and look through the diffraction grating end.
3. Hold pieces of red and blue glass or cellophane over the slit, one at a time, and then both at once, while pointing the spectroscope at the sky.
4. Have the students compare light from various sources. For example, a light bulb, NaCl, or other salts heated in an open flame, or gas discharge tubes.
5. In each case, have the students sketch what they see using colored pencils.

PRECAUTIONS:

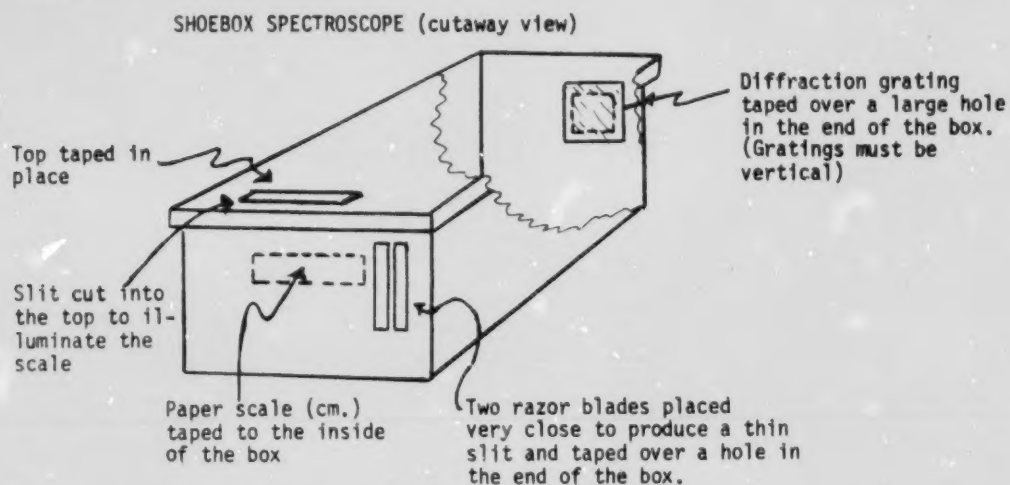
1. DO NOT AIM THE SLIT DIRECTLY AT THE SUN because eye damage could occur.
2. Try to make sure each student is actually observing a spectrum; this might be accomplished by checking their colored pencil drawings of what they see.
3. The lab itself will serve only to stimulate the students' interest; topic understanding must be accomplished during the postlab session.

TYPICAL RESULTS:

1. Student drawings of the sun's continuous spectrum should represent a generalized rainbow of colors.
2. Drawings of sun's spectrum filtered by the cellophane should show darkened areas near the blue end when red cellophane is used and near red end when blue cellophane is used.
3. Drawings of heated NaCl or discharge tubes should demonstrate individually spaced bright lines which are characteristic of that element or substance. The location of the lines should correspond to the relative position in the spectrum for that color.

MODIFICATIONS:

Construct shoebox spectroscopes for improved viewing of the spectra. (See labeled diagram.)

REFERENCES:

Investigating the Earth, pp. 142-149, Teacher's Guide, pp. 183-186.

V-A-1a: ELECTROMAGNETIC SPECTRUM

QUESTION:

What are the properties of electromagnetic energy?

INTRODUCTION:

You have seen and felt the effects of solar energy all of your life. In order to find out more about the properties of this energy, we can use an instrument called a spectroscope. In this investigation you will use this instrument to investigate light from various sources including the sun.

OBJECTIVES:

When you finish this investigation you should be able to:

1. list the colors of the visible spectrum in correct order.
2. describe the effect of a filter on the solar spectrum.

METHOD:

1. Carefully observe a portion of the bright sky through the slit in your spectroscope. DO NOT LOOK DIRECTLY AT THE SUN. Using colored pencils, sketch what you see in the box below.

Bright sky.

2. Hold pieces of red and blue glass or cellophane over the slit, one at a time, and both at once, while pointing the spectroscope at the sky. Sketch what you see.

Bright sky with blue filter.

Bright sky with red filter.

Bright sky with both filters.

3. Carefully observe the spectrum of various other energy sources provided by your teacher. Sketch what you see below. Label each.

QUESTIONS:

1. How many color zones did you see in the solar spectrum?
2. How do the zones compare in size?
- (A-1.13) 3. What effect does the blue filter have on the observed solar spectrum? The red filter?
4. What is the effect, in general, upon the observed spectrum of a color filter corresponding to one of the spectrum colors?
5. What are the similarities and differences among the spectra produced by the different sources?
6. What do you think causes the differences in spectra?
7. What do you think is meant by the statement "the spectrum of a source is like a fingerprint"?
- (A-1.11) 8. Under what conditions does a potential source appear to produce a spectrum? Why?
- (A-1.12) 9. Which color in the visible spectrum has the longest wave length? the shortest? the greatest frequency? the smallest?
10. Where is the visible spectrum located with respect to the total electromagnetic spectrum?
- (A-1.22) 11. How is the sun's energy distributed among the various portions of the electromagnetic spectrum?

V-A-2a: HEAT TRANSFER

QUESTION:

How can energy be transferred?

MATERIALS:

Heat transfer kit, or two polystyrene coffee cups, and a 12-inch aluminum bar bent to a U shape, two high temperature thermometers (-10° to 110°C).

SUGGESTED APPROACH:

1. Ask students how they think energy can be transferred. The discussion should lead to the three basic ways: conduction, convection, and radiation. In this lab they will investigate conduction.
2. Have students carry out the investigation and graph their results.
3. In the postlab discussion, help them develop a molecular model that will explain the observed results. The high kinetic energy molecules on the hot end transfer their kinetic energy from one molecule to another until kinetic energy equilibrium is reached throughout the system.

PRECAUTIONS:

1. The energy gained by the cool cup will not equal the energy lost by the hot cup. This may trouble some of the students who are aware enough to recognize it. Ask them to suggest reasons for this. Eventually they should suggest that the aluminum bar may radiate heat into the air around it. This is not the only reason and the students may come up with many more.
2. Caution should be taken to make sure both thermometers read the same at room temperature before the investigation is begun.

TYPICAL RESULTS:

The results should graphically show a reduction in heat in the hot cup, and a heat gain in the cool cup. As a result of the heat lost through the aluminum bar, the heat lost by the hot water will be greater than the heat gained by the cool water. Students should be led to realize that the difference between the heat lost and the heat gained is a result of other variables and NOT a result of experimental error.

MODIFICATIONS:

The readings of temperatures can be extended for several hours. The results may eventually indicate that both cups become sources while the bar is the sink.

REFERENCES:

Investigating the Earth, pp. 130-131, Teacher's guide, pp. 175-176.

V-A-2a: HEAT TRANSFER

QUESTION:

How can energy be transferred?

INTRODUCTION:

Heat energy transferred from a high heat "source" to a low heat "sink" is the basic principle behind most of our engines that do work for us. A tremendous amount of heat energy is stored in the ocean. If an appropriate heat sink could be found, the resulting heat transfer could do a great deal of work for us. In this investigation, you will observe and analyze the flow of heat energy.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. indicate the direction in which energy would be transferred between two objects, given their temperatures.
2. identify conditions in which heat is lost or gained, and determine the amounts and relative rates of heat exchange, given a graph of temperature vs. time of two equal masses of water that are exchanging energy.

METHOD:

1. Put boiling water (100°C) in one calorimeter, and water at room temperature (approximately 25°C) in the other. Place the two cups in such a position that one end of the U-shaped aluminum bar can be inserted into the water in one cup, and the other end of the bar inserted into the water in the other cup. Place a thermometer in each cup.
2. Record the temperature reading of each thermometer at 4-minute intervals for 20 minutes.
3. Graph your results for both cups.

QUESTIONS:

- (C-1.11) 1. In what direction does the energy flow? What is your evidence?
- (C-1.12) 2. How does the energy lost compare with the energy gained? Why?

- (A-2.11) 3. How is the energy transferred from the water in one calorimeter to the water in the other?
4. What could you do to make the final temperature readings higher?
5. How do the rates of energy exchange in each cup compare?

V-B-1a: CHANGES IN STATE

QUESTION:

What are some energy transformations that can be observed in earth processes?

MATERIALS:

Each group should be provided with a beaker (at least 100 ml.), high temperature thermometer (-10°C to 110°C), ring stand with ring clamp and wire gauze, crushed ice, heat source.

SUGGESTED APPROACH:

1. Ask the students what kind of a relationship exists between heat and temperature. Can the relationship be demonstrated and measured? How? Many possibilities exist and original thinking by the students should be encouraged.
2. Have the students set up apparatus, make appropriate measurements, and graph their results.
3. Class discussion of results should lead to the conclusion that a direct and constant relationship between heat and temperature does not always exist.

PRECAUTIONS:

1. Caution should be exercised since the students will be working with boiling water.
2. Constant stirring of the mixture is very important for accurate temperature determinations.
3. The heat source should not be altered after temperature readings have begun. The basic assumption is that heat is being added at a constant rate and is proportional to time. Students should be made to realize this.
4. Adequate time must be allowed for temperature readings to be taken as the temperature rises from zero or below to approximately 100°C . This time will vary depending on heat source, however; 15 to 20 minutes should be allowed.
5. Many of the students will not be expecting the results obtained, and may have a tendency to try to connect the points on the graph with a straight line.

TYPICAL RESULTS:

It is unlikely that all groups will produce graphs which show heat of fusion as well as vaporization. It may be desirable to have a member of each group sketch the group's graph on the chalkboard or on an overhead projector so that the graphs may be considered together. In this way you should be able to show a tendency for the curves to flatten out at 0°C . and at 100°C .

MODIFICATIONS:

If adequate equipment is not available, the heat of fusion portion only may be done by allowing ice to melt at room temperature.

Students can investigate the change in state of mothball crystals. This involves melting mothball crystals in a test tube using a water bath. A thermometer should be inserted into the melted material and readings taken every 30 seconds until crystallization is complete. Additional information can be found in many physics laboratory manuals.

REFERENCES:

Investigating the Earth, pp. 138-140, Teacher's Guide, pp. 180-182.

V-B-1a: CHANGES IN STATE

QUESTION:

What are some energy transformations that can be observed in earth processes?

INTRODUCTION:

In this investigation you will be adding energy to a common earth material. As you do so, you will be measuring the effects of this addition of energy. Try to determine where the energy is coming from, and where it is going.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. identify conditions of energy change (e.g., kinetic energy increase or decrease, potential energy increase or decrease) when given a graph showing temperature change as a function of time for water which is heated from a temperature below 0°C. to steam.
2. describe how the heating abilities of two samples of a substance compare at the same temperature, but in different phases.

METHOD:

1. Set up ring stand with ring clamp and wire gauze at the appropriate height above the heat source. Turn on and adjust heat source.
2. Add crushed ice to the beaker and quickly insert thermometer into it, place beaker on wire gauze over the heat source.
3. Begin temperature readings immediately and continue taking readings at 1-minute intervals, continuing for at least 3 minutes after the water begins to boil.
4. Include in your data times when ice begins to melt, when it is entirely melted, and when the water begins to boil.
5. Throughout the time readings are being taken, you should stir the solution gently with the thermometer.
6. Graph your results.

QUESTIONS:

1. What is the relationship between energy input (heat) and temperature change?
2. When was the temperature changing at the fastest rate?
- (B-1.11) 3. When was the temperature changing at the slowest rate?
- (B-1.12) 4. What is the cause of the major variations in the rate of temperature change?
5. How does water at 100°C. compare to steam at 100°C. in its ability to heat other materials?
6. How does ice at 0°C. compare to water at 0°C. in its ability to cool other materials?
- (C-1.11) 7. In what direction does energy flow?
- (C-1.12) 8. If the system used in the investigation is closed (no energy entering or leaving), what is the relationship between heat lost and heat gained?

V-B-1b: ENERGY ABSORPTION

QUESTION:

What are some energy transformations that can be observed in earth processes?

MATERIALS:

Shiny metal can, black metal can, insulating lids with slits for thermometers, two thermometers low range (-20°C . to 50°C), heating lamp, graph paper.

SUGGESTED APPROACH:

1. Have each group of students set up apparatus and carry out the investigation as directed by student sheet.
2. Have the entire group discuss their results.

PRECAUTIONS:

1. Make certain all the thermometers being used are in workable condition and at the same temperature before the light is turned on.
2. Check student apparatus to make sure thermometers are suspended in the middle of the can and are not touching the sides or bottom of the can.

TYPICAL RESULTS:

Results should be adequate to demonstrate the differential heating characteristics of dark - and light-colored objects.

MODIFICATIONS:

Dull and shiny black (or any color) cans give interesting results. Dark - and light-colored soils may be used instead of the cans. However, the additional variable, specific heats, may influence the results.

REFERENCES:

Investigating the Earth, pp. 130-131; Teacher's Guide, pp. 173-175.

V-B-1b: ENERGY ABSORPTION

QUESTION:

What are some energy transformations that can be observed in earth processes?

INTRODUCTION:

People living in tropical climates often wear light-colored clothing, while people in higher latitudes dress in darker colors. Is this coincidence or is there a reason? Have you ever observed any similar reaction to earth materials? How does the temperature of an asphalt surface compare to that of light-colored sand? This investigation may help you answer some of these questions.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. state verbally which of two given materials of different color is likely to absorb the most heat energy in a given period of time, and which will radiate heat energy most quickly.
2. interpret graphs representing the temperature changes of two objects which are being heated, and identify the one of greater heating rate.

METHOD:

1. Place the heat lamp at equal distances from the dark and light colored cans. Push the thermometers through the slot in the top of the cans. MAKE CERTAIN THERMOMETER DOES NOT TOUCH SIDES OR BOTTOM OF CAN.
2. Turn the light on and record the temperatures each minute for 10 minutes, or until the temperature reaches 45°C. Turn the light off, remove it without disturbing the cans, and record the temperatures each minute for 10 more minutes.
3. Draw a graph for the temperature change in each can.

QUESTIONS:

1. Which can heats faster?
2. Which can cools faster?

3. Which can absorb energy faster? What is your evidence?
- (A-1.14) 4. Which can radiate energy faster? How do you know?
- (B-1.31) 5. What determines the rate at which energy is absorbed?
- (A-1.13) 6. What can happen to the incoming energy that reaches the surface of the cans?
7. What process was responsible for the energy transfer in this investigation?
8. What forms of energy did you observe?
- (B-1.32) 9. How do you think the wavelength of the energy absorbed by the cans compares with the wavelength radiated back? Explain.

V-C-1a: SPECIFIC HEAT

QUESTION:

What inferences can be drawn about the total energy within a closed system?

MATERIALS:

Samples of aluminum, copper, granite, and water having as nearly equal masses as possible. Also needed are a 500-ml. beaker (a larger high temperature container works better if available), calorimeter cup or polystyrene coffee cup, thermometer (high range -10°C. to 110°C.), clock, thread, and heat source (hot plate or Bunsen burner). Density kit materials can be used.

SUGGESTED APPROACH:

1. Ask students if a certain amount of heat energy would produce equal temperature changes in equal masses of different materials.
2. Ask for suggestions as to how this question could be investigated. This investigation lends itself to a variety of approaches. Encourage students to try any reasonable procedure. You may wish to have them check proposed procedures with you as some may clearly not work or be difficult to carry out.
3. Use a student-suggested method if possible; if not, use the approach suggested in the student handout sheet.
4. You may wish to heat all materials in one container at a central desk.

PRECAUTIONS:

1. Students should be cautioned regarding the handling of hot water and/or objects.
2. Use a small enough volume of water in the calorimeter cup so that a sufficient temperature change will be recorded.
3. Leave all three of the objects suspended in the boiling water for a long enough period of time before class (suggested 1/2 hour) so they are heated to about 100°C. throughout.
4. Continue to take calorimeter cup readings until no more temperature increase is recorded.
5. Be sure the masses of all the objects are about equal or results may be misleading.

TYPICAL RESULTS:

Results should be adequate to point out the relative (if not the quantitative) differences in specific heat among the various materials.

REFERENCES:

See high school and college physics textbooks.

V-C-1a: SPECIFIC HEAT

QUESTION:

What inferences can be drawn about the total energy within a closed system?

INTRODUCTION:

During colonial days, stones were sometimes heated in the fire and then dumped into special containers and placed at the foot of the bed to keep the occupant's feet warm. Would it matter what kind of stones were used? Would equal masses of different materials give off the same amount of heat? This investigation will help you answer this question.

OBJECTIVES:

When you finish this investigation you should be able to:

1. identify the material with the greatest specific heat, given the amount of temperature change equal masses of various materials undergo when placed in the same mass of water.
2. indicate which would produce the greatest temperature change when equal masses of the materials are added to the same mass of water, given the specific heat of various materials.

METHOD:

1. Suspend equal masses of aluminum, copper, and granite in a container of boiling water. Keep the water over the heat source so that it continues to boil even after these objects are placed in it.
2. Fill the calorimeter about $\frac{2}{3}$ full with a known mass of room temperature water. Use this same amount of water for all future steps.
3. Remove the aluminum from the boiling water, and place it in the calorimeter. Record the time and temperature. Measure and record the temperature at 1-minute intervals until no change in temperature is noted.
4. Repeat the previous step using first the copper and then the granite. Be sure to use fresh water at room temperature with each new piece of material.
5. As a final step, pour boiling water with a mass equal to that of one of the solids into the calorimeter cup. Make the same measurements as in the previous steps.

QUESTIONS:

1. Which sample caused the greatest temperature change?
2. Which sample caused the least temperature change?
- (C-1.12) 3. How does the amount of energy lost by one substance compare with the amount gained by the other?
- (C-1.13) 4. How does the amount of temperature change for the various materials compare with the amount of energy transferred?
5. Which sample required the greatest time to effect the temperature change? Which the least?
6. List the samples in order of temperature change...greatest first. List the samples in order of time required to cause the change...greatest first. How do the lists compare?
- (C-1.14) 7. Which of the substances has the greatest specific heat? the least?
- (C-1.15) 8. How can the amount of heat lost and gained be determined?
- (C-1.11) 9. For each case, in which direction did the energy flow?

topic VI

What Happens To Solar Energy That Reaches The Earth?

Time Emphasis: 5 days

TOPIC OUTLINE	INVESTIGATION	A-1a	A-1b	A-1c	A-1d	B-1a	LTI - #14												
	Estimated Time (Periods)	2	0½	1½	2	1½	LTI												
A. Insolation at the earth's surface	A-1 Insolation factors	What Are Some Factors Which Affect Insolation?																	
	A-1.1 Angle	A-1.11																	
		A-1.12																	
		A-1.13																	
	A-1.2 Duration	A-1.21																	
		A-1.22																	
		A-1.23																	
		A-1.24																	
	A-1.3 Absorption	A-1.31																	
		A-1.32																	
	A-1.4 Reflection	A-1.41																	
		A-1.42																	
		A-1.43																	
	A-1.5 Scattering	A-1.51																	
		A-1.52																	
	A-1.6 Energy conversion	A-1.61																	
B. Terrestrial radiation	B-1 Radiation factors	What Are Some Factors Which Affect Terrestrial Radiation?																	
	B-1.1 Material radiation	B-1.11																	
	B-1.2 Gases	B-1.21																	
	B-1.3 Balance	B-1.31																	
		B-1.32																	
		B-1.33																	
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1																	
	Measurement Skill	PIO-2																	
	Creating Models	PIO-3																	
	Analysis of Error	PIO-4																	
	Data Analysis	PIO-5																	
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Angle of Insolation																
			Solar Altitude Observations																
			Duration of Insolation																
			Land and Water Temperatures																
			Terrestrial Radiation																
			Soil Temperature																

VI-A-1a: ANGLE OF INSOLATION

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Light source (200W), thermometer (low range), test tube, one-hole stopper, protractor.

SUGGESTED APPROACH:

1. Review the appearance of the sun's path and the seasonal changes of this path. Ask if the position of the sun has any effect on its ability to heat the earth. Discuss this briefly and suggest the following investigation as one method of measuring such an effect.
2. Have student: fill a test tube with water, put a thermometer through a one-hole stopper, and stopper the test tube. Be sure the thermometer bulb is not touching the walls of the tube. Place a 200-watt light bulb about 20 cm. away from the test tube and at an angle of incidence of 90° . Turn the light on for 10 minutes; record the temperature at 1-minute intervals.
3. Repeat step 2 for angles of incidence of 60° , 30° , and 0° . Be sure to change the water each time. It is easier to change the angle of the test tube than to change the angle of the light. If enough thermometers are available, all angles can be done at the same time, using a different test tube for as many different angles as are desired.
4. Plot the temperature vs. time for each angle of insolation on the same graph.
5. Lead students in a discussion of the effects of the angle of incidence on heating. The model should be related to the earth-sun situation. Copies can be made of the accompanying diagram to illustrate the seasonal effects.

PRECAUTIONS:

1. Results near an angle of 0° may show more heating than would be expected because of limitations of the model. The students may wish to extrapolate values for 0° rather than measure them.
2. Do not get any water on the hot light bulb. If the light bulb used is a heat lamp, avoid looking directly at it.

TYPICAL RESULTS:

As the angle of incidence is decreased, the temperature change should decrease.

MODIFICATIONS:

1. The investigation can be done using thermometers with pieces of black paper taped to them, and changing the angle of incidence by tipping the thermometers.
2. Give students a statement of purpose; e.g., what effect does the angle of incidence have on heating power? From this statement have the students design and carry out their own procedures for answering the question.

3. Tape small thermometers to various latitudes on a large globe. Hold a 200 watt lamp at least a meter away and directed somewhere between $23\frac{1}{2}^{\circ}\text{N}$ and $23\frac{1}{2}^{\circ}\text{S}$. Take temperature readings every minute and graph the data. Be careful that the temperature does not go beyond the range of the thermometers. This could be done with the sun during globe rectification if a large globe is used.

REFERENCES:

Investigating the Earth, pp. 250-252; *Teacher's Guide*, pp. 303-305.
Our Planet in Space, pp. 138-139, 144-145.

VI-A-1a: ANGLE OF INSOLATION

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

Sometimes the sun is high in the sky; at other times it is quite low. Where it is depends on the season and on the time of day as you have previously observed. How does this changing angle (the angle of incidence) affect the temperature? In this investigation you will use a model to find an answer to the question.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. describe the relationship between insolation and the angle of incidence.
2. describe how each of the factors, time of day, latitude, and season, influence the heating effect of insolation at a particular location.

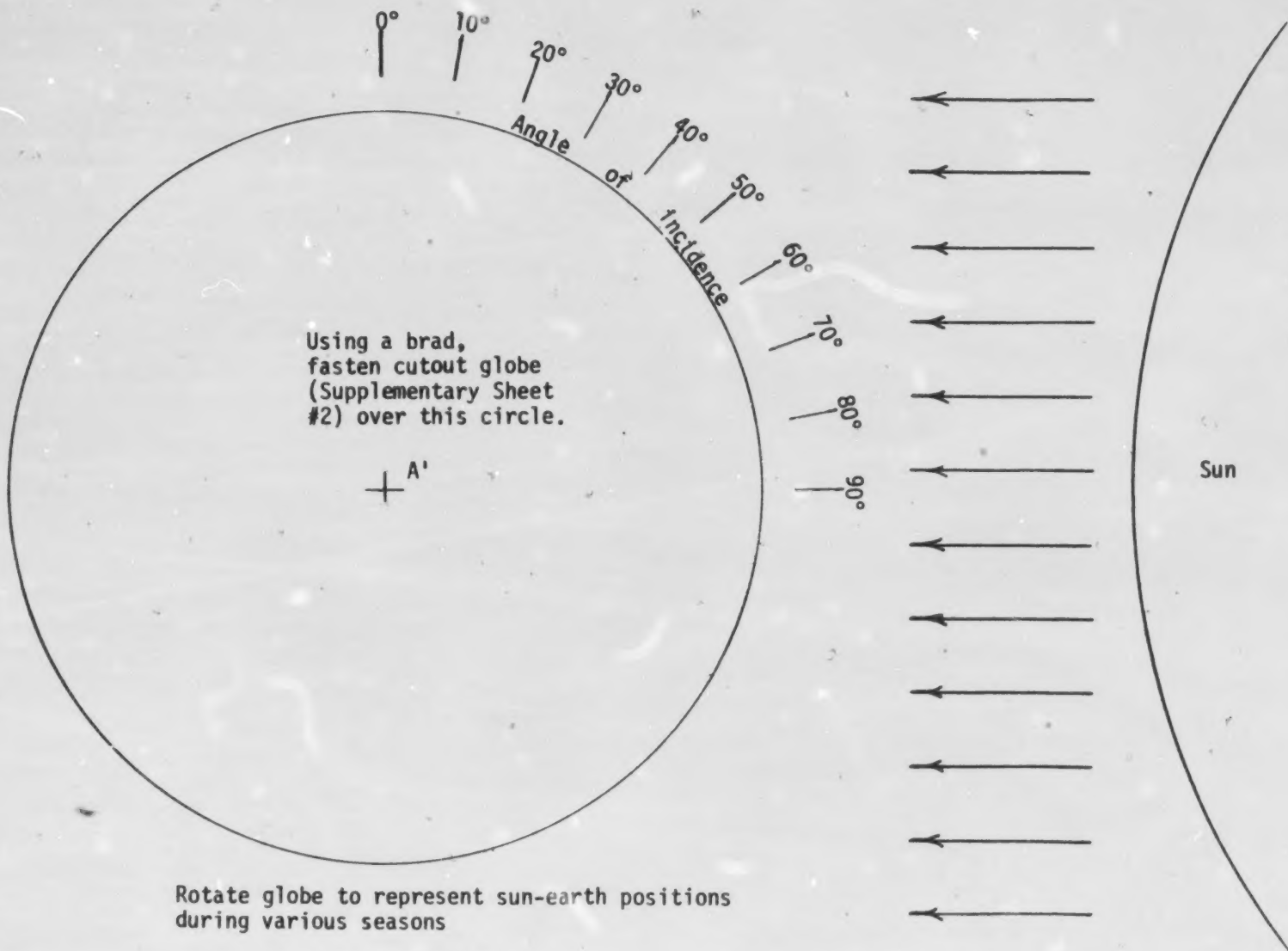
METHOD:

1. Fill a test tube with water, put a thermometer through a one-hole stopper, and stopper the test tube. Place a 200 watt light bulb about 20 cm. away and place the test tube at an angle of 90° to the light. Turn on the light for 10 minutes and record temperature readings at 1-minute intervals.
2. Repeat step 1 for angles of 60° and 30° and 0° .
3. Graph the data for all angles on the same set of axis.
4. Use the earth model provided by your teacher to study the effects of latitude variation and seasonal change on the intensity of insolation per unit area.

QUESTIONS:

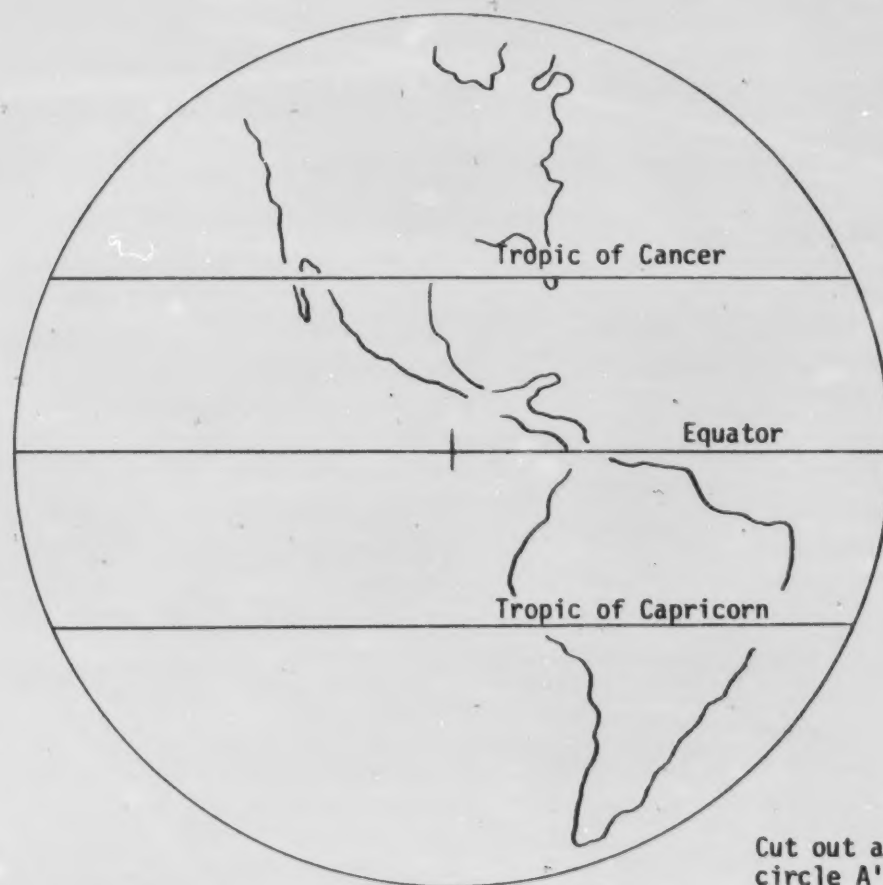
1. What effect does increasing the angle of incidence have on the temperature change in the test tube?
2. What is the pattern of temperature change as the angle changes from 0° to 90° ? Why?

- (A-1.11) 3. What effect does increasing the angle of incidence have on the intensity of insolation?
- (A-1.12) 4. How does a change in latitude affect insolation?
- (A-1.13) 5. How does the angle of incidence of insolation at any location change between sunrise and sunset?



SUPPLEMENTARY SHEET #1

VI-A-1a



Cut out and fasten over circle A', using a brad through the centers, so that the top circle can be rotated.

VI-A-1a

VI-A-1b: SOLAR ALTITUDE OBSERVATIONS

QUESTION:

What are some factors which affect insolation?

SUGGESTED APPROACH:

1. Initiate a discussion about the altitude of the sun at noon. Raise questions such as: How high is the sun at noon? Is the noontime altitude of the sun always the same? What is the pattern of change in noontime altitude?
2. Have the students plot the data from the table (see supplementary sheet). This can best be done as a homework assignment.
3. Discuss student answers to the preliminary questions and those on the student sheet.

PRECAUTIONS:

Students may need some assistance in setting up the graph axis.

TYPICAL RESULTS:

The resulting graph is a sinusoidal curve which should clearly show the pattern of change of solar noontime altitude during the year.

MODIFICATIONS:

1. If time permits, have the students measure the altitude of the noontime sun.

REFERENCES:

Investigating the Earth, pp. 92-94, Teacher's Guide; pp. 131-133.

VI-A-1b: SOLAR ALTITUDE OBSERVATIONS

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

How high up in the sky is the sun at noontime? Is the sun's noontime altitude always the same? Observations of the sun have been made at noontime for the period of a year. You will have an opportunity to analyze this data and draw some inferences about it.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. describe the relationship between altitude change and the time of year at this latitude.
2. indicate the time of year when the altitude of the sun is greatest and the time when it is least at any latitude, given a graph or table of data.
3. describe the effect of a change in solar altitude on the intensity of insolation.

METHOD:

1. Graph the altitude of the noontime sun for the days given in the data table.
2. Analyze the graph and answer the questions below.

QUESTIONS:

1. What time of year is the altitude greatest? least?
2. What is the difference between the highest and lowest altitudes?
3. What is the cause of this change?
- (A-1.11) 4. On what date would the intensity of insolation be greatest?
5. What was the approximate latitude at which these readings were taken?
6. How would the date be affected if the latitude at which the readings were taken was increased?

ALTITUDE OF THE SUN AT HIGH NOON

Date	Altitude	Date	Altitude
Jan. 1	24° 55'	July 10	70° 21'
Jan. 10	25 54	July 20	68 50
Jan. 20	27 41	July 30	66 44
Jan. 30	30 06	Aug. 10	63 50
Feb. 10	33 21	Aug. 20	60 45
Feb. 20	36 45	Aug. 30	57 20
March 1	40 27	Sept. 10	53 17
March 10	43 32	Sept. 20	49 27
March 20	48 32	Sept. 30	45 34
March 30	51 25	Oct. 10	41 42
April 10	55 36	Oct. 20	37 59
April 20	59 12	Oct. 30	34 31
April 30	62 29	Nov. 10	31 07
May 10	65 23	Nov. 20	28 31
May 20	67 47	Nov. 30	26 30
May 30	69 38	Dec. 10	25 10
June 10	70 57	Dec. 20	24 35
June 20	71 26	Dec. 30	24 46
June 30	71 14		

VI-A-1c: DURATION OF INSOLATION

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Light source, thermometer, container of soil.

SUGGESTED APPROACH:

1. Place the thermometer 1 cm. below the surface of the soil, and place the light source 20 cm. above it (closer if a low wattage bulb is used).
2. The light source should be turned on and off in a pattern which simulates the variation in the length of day and night during the year. Provide students with data regarding the length of day and night at the various times of the year (see note below). Have them suggest a sequence of times that could be used for the model. A possible sequence of times would be:

<u>Date</u>	<u>Light on (sec.)</u>	<u>Light off (sec.)</u>
March 23	120	120
April 23	130	110
May 23	145	95
June 23	150	90
July 23	145	95
August 22	130	110
September 22	120	120
October 22	105	135
November 22	95	145
December 22	85	155
January 22	95	145
February 21	105	135
March 23	120	120

Note: The above numerical values were obtained by multiplying by 10 the approximate number of hours of daylight and darkness at 42°N latitude on the given dates.

3. Temperature readings should be taken just before the heating period or just after the heating period, but not both.
4. Pupils should graph the temperature readings vs. time. Each graph will be a model of the earth's absorption and radiation pattern.
5. A general statement by each group of what happened to the temperature of the soil they used will show at what time of the year the soil is being warmed and when the soil is cooling.

PRECAUTIONS:

1. Better results are obtained if the setup is brought to a state of radiative balance before the sequence is begun. This can be accomplished by alternately turning the light on for 2 minutes and off for 2 minutes until the change in temperature stabilizes.
2. Remove the lamp during periods when it is off.

TYPICAL RESULTS:

1. Students should have little difficulty detecting periods of absorption and radiation.
2. Students should be able to detect a heating lag. The maximum temperature will probably be reached later for the model than it occurs on the earth. This can be related to the fact that for the earth the angle of insolation also changes.

MODIFICATIONS:

1. The sequence may be halved so as to run from vernal equinox to autumnal equinox or from autumnal equinox to vernal equinox. The former should indicate the time of maximum temperature; the latter the time of minimum temperature.
2. The ratio of daylight and darkness hours to light on and off times may be changed depending on the total amount of available time.
3. As an additional variable, the angle of insolation can also be varied to produce a model more closely related to the earth.
4. An additional graph of input energy (measured in terms of the amount of time the light is on) may be plotted on the same axis as temperature, but using an appropriate scale. This will enable the student to make a direct comparison of cause and effect, and temperature lag.

REFERENCES:

Investigating the Earth, pp. 158-161.

VI-A-1c: DURATION OF INSOLATION

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

What is the effect on the earth's temperature of a changing ratio of daylight and darkness? In this investigation, you set up a model using the daylight-darkness ratio for the Northern Mid-latitudes. From this model, some relationships may be inferred concerning the seasonal variation of insolation.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. given a graph showing the variations in temperature produced by variations in the duration of insolation:
 - a) identify patterns of annual maximum and minimum temperatures,
 - b) identify periods of absorption and radiation,
 - c) relate maximum and minimum temperatures to maximum and minimum duration of insolation.
2. describe the ways in which the model is analogous to the earth and the ways in which it is not.

METHOD:

1. Set up a container of soil. Place the thermometer bulb 1 cm. below the surface of the soil and the light source 20 cm. above it (closer if a low wattage bulb is used).
2. Turn the light source on and off in a pattern which simulates the variation in length of daylight during the year at your latitude.
3. Record temperature readings just before the light is turned on or just before it is turned off, but not both.
4. Graph your results (time vs. temperature).

QUESTIONS:

- (A-1.21) 1. What effect does an increase in the duration of insolation have upon the soil temperature?

- (A-1.23) 2. At what time of the year is the duration of insolation at a maximum?
- (A-1.24) 3. How does the time of maximum surface temperature compare with the time of maximum duration of insolation for the model? for the earth? Account for any differences.
- (A-1.22) 4. How is the duration of insolation related to the various seasons?
- (A-1.22) 5. How would the duration of insolation during the year be affected by an increase in latitude?

VI-A-1d LAND AND WATER TEMPERATURES

QUESTION:

What are some factors which affect insolation?

MATERIALS:

Three plastic hemispheres, six thermometers (low range C.^o), dark-colored soil, light-colored soil (sand), water, heat lamp.

SUGGESTED APPROACH:

1. Initiate a discussion about the abilities of land and water to change temperature when heated. The comparison of land and water temperatures as observed at a beach can be used to relate to a probable common experience among students.
2. Have the students assemble apparatus as directed on handout sheet. Then make and record appropriate time and temperature measurements. Prepare graphs for both soils and the water.
3. Encourage students to interpret their own graphs and try to construct a mental model to explain what energy transformations are taking place and why. Have them relate the results to previous investigations in topic V and to their own experiences outside of school.

PRECAUTIONS:

1. Check to make sure thermometers are not buried too deeply in the soil. Soils are poor conductors of heat; and if the thermometers are buried too deeply, no change in temperature will result. The soil should just cover the bulb on the thermometer.
2. Be sure to use dry soils.
3. All three thermometer bulbs should be placed equidistant from the heat source.
4. Thermometers should all start at the same temperature.
5. Students will probably attempt to oversimplify the interpretations of their results. This investigation deals with various factors, such as: specific heats of the various materials; reflective abilities of the surfaces of each, including color; the ability to distribute heat energy by conduction or convection; and the depths to which energy can penetrate directly.

TYPICAL RESULTS:

If the apparatus is set up as directed, the temperature change should be greatest for the dark soil and least for the water.

MODIFICATIONS:

1. This could be done with only one type of soil and water. The additional soil serves to illustrate that all solid earth materials do not absorb energy at equal rates. Later in the course, this investigation can be related to land and sea breezes. Air convection currents are also set up as a result of unequal heating of solid earth

materials; however, the result is not as dramatic.

2. Students could be shown aerial photographs and be asked to interpret the tone (black and white shading) of various earth materials such as sand, clay soil, water, and forest vegetation.

REFERENCES:

Investigating the Earth, pp. 172-173; Teacher's Guide, pp. 209-211.

VI-A-1d: LAND AND WATER TEMPERATURES

QUESTION:

What are some factors which affect insolation?

INTRODUCTION:

Have you ever noticed that on a hot summer's day the sand on the beach becomes uncomfortably hot while the water seems cool when you enter? However, if you have ever gone swimming early in the morning, you will remember that the reverse was true, the sand was cool and the water felt warm. How could this apparent change take place?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. identify a graph for soil and a graph for water, given two unlabeled temperature vs. time graphs for samples of the materials which have been exposed to a heat source.
2. identify areas of lowest temperature, shown two diagrams, each showing a shoreline between a body of water and land, one labeled "day" and the other "night."

METHOD:

1. Fill each of three plastic hemispheres about 1/3 full; one with water, one with dry, light-colored soil (sand), and the other with dry, dark-colored soil.
2. Place two thermometers in each hemisphere. One should be placed just under the surface of the material and the other just above the surface. This is accomplished best in the soil by making a small depression with your finger, placing the bulb of the thermometer in the depression, and then sprinkling loose soil over the thermometer bulb until it is just covered.
3. Place a heat lamp 20-30 cm. above the hemispheres, and turn it on.
4. Record the temperatures on the thermometers each minute for 10 minutes.
5. Turn off the light and continue recording temperatures each minute for 10 minutes.

6. Graph your data.

QUESTIONS:

1. Which received more energy from the lamp, the soils or water?
- (A-1.32) 2. How did the temperatures in and above the hemispheres vary?
3. What characteristics of the materials could explain the variations in temperatures of the materials?
4. What effects do the differences in heating and cooling rates of land and water surfaces have upon the atmospheric conditions?

VI-B-1a: TERRESTRIAL RADIATION

QUESTION:

What are some factors which affect terrestrial radiation?

MATERIALS:

Two containers of soil, two thermometers (low range C.^o), one plastic hemisphere, heat source (lamp or sun).

SUGGESTED APPROACH:

1. Initiate a discussion about radiation from the earth. Have students suggest factors which may influence the amount of energy radiated from the earth's surface. This discussion can be focused on the effect of the atmosphere on surface radiation.
2. Have the students set up the apparatus as described on the student sheet and conduct the investigation.

PRECAUTIONS:

1. Care should be taken in relating the model to the earth. The results should be analogous to the effect of the atmosphere but not entirely because of limitations of the model. For example, the hemisphere restricts air circulation which is not true for the earth.

TYPICAL RESULTS:

The soil in the covered container should heat up slower and cool slower.

MODIFICATIONS:

Use additional hemispheres of soil; introduce atmospheres containing dust, water vapor, smoke, or carbon dioxide. Cover them and test for the effect of each material on surface radiation.

REFERENCES:

Investigating the Earth, pp. 159-161.

VI-B-1a: TERRESTRIAL RADIATION

QUESTION:

What are some factors which affect terrestrial radiation?

INTRODUCTION:

What is the effect of the atmosphere on radiation from the earth's surface?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. indicate conditions of rapid heating and rapid cooling, given a time vs. temperature graph of covered and uncovered soil that has been exposed to a light source.
2. suggest some factors that could account for differences in the heating and cooling rate between the covered and uncovered soil.

METHOD:

1. Place the same amount of soil in each of two containers. A thermometer should be buried 1 cm. deep in the soil in each container.
2. Place both containers under a heat lamp or in the sun until the temperatures in both have risen 15°-20° above room temperature.
3. Place a plastic hemisphere over one of the containers.
4. Record the temperature in both containers every 2 minutes for at least 20 minutes.
5. Graph your results (time vs. temperature).

QUESTIONS:

1. Which container of soil received the most energy from the heat source?
2. In which container of soil did the temperature change the most? Why?

- (A-1.31) 3. In what ways is the effect of the cover on temperature changes similar to the effect of the atmosphere? In what ways is it not?
- (A-1.41) 4. How do the wavelengths of the radiation absorbed and radiated back by the soil compare? How do they compare for the earth?
- (B-1.11) 5. What materials in the atmosphere produce the same effect for the earth that the cover produced on the soil?

t o p i c VII

Time Emphasis: 16 days

[illegible]

TOPIC OUTLINE	INVESTIGATION		A-1a	B-1a	C-1a	C-1b	C-3a	C-3b	C-4a	LT1 - #12	FE - #5								
	Estimated Time (Periods)		1	3	1	1	D	1	1	LT1 - #12	FE - #5								
	C-2 Moisture and energy transfer		How Are Moisture and Energy Transferred in the Atmosphere?																
	C-2.1 Density differences	C-2.11																	
		C-2.12																	
		C-2.13																	
		C-2.14																	
		C-2.15																	
	C-2.2 Wind speed and direction	C-2.21																	
		C-2.22																	
		C-2.23																	
	C-2.3 Adiabatic changes	C-2.31																	
	C-3 Release of moisture and energy within the atmosphere		How Are Moisture and Energy Released Within the Atmosphere?																
	C-3.1 Condensation and sublimation	C-3.11																	
		C-3.12																	
		C-3.13																	
	C-3.2 Cloud formation	C-3.21																	
	C-4 Release of moisture and energy from the atmosphere		How Are Moisture and Energy Released From the Atmosphere?																
	C-4.1 Precipitation	C-4.11																	
	C-4.2 Wind-water interaction	C-4.21																	
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1																	
	Measurement Skill	PIO-2																	
	Creating Models	PIO-3																	
	Analysis of Error	PIO-4																	
	Data analysis	PIO-5																	
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Weather Watch Analysis																
			The Synoptic Weather Map																
			Evaporation																
			Vapor Pressure																
			Adiabatic Cooling & Cloud Formation																
			Dew Point - Cumulus Cloud Formation																
			Air-Water Interactions																
			Haze																
			Beach																

VII-A-1a: WEATHER WATCH ANALYSIS

(Continuation of LTI #1 - Weather)

QUESTION:

What relationships between atmospheric variables can be determined from local observations?

MATERIALS:

Weather watch data, U.S. weather maps for the time period of the weather watch data.

SUGGESTED APPROACH:

1. The major portion of this investigation should be spent in discussion, since the students should have been looking for relationships between factors during the time the data were collected. Ask them which factors they think are related; be sure that they can demonstrate to each other that their hypotheses are reasonable, based on the data; encourage students to challenge each other.
2. List on the board all the relationships that are suggested. Have the students indicate which relationships are strong (almost always true) and which are weak (sometimes not true); if possible, estimate a percentage probability. Also, have them indicate whether the relationships are direct or inverse.
3. Lead the students in a discussion of why the factors listed are related in the manner described. Clarify their ideas with leading questions.
4. Distribute weather maps for the period covered by the weather watch. Ask students to study the weather maps and to look for any symbols which seem to be correlated to their local weather data. Discuss any correlations that have been found.
5. Ask students how the results of this investigation could be used to aid them in predicting weather. Give them some sample sets of data (taken from the weather watch). Ask them to predict the next day's weather; then give them the date for the initial data and have them check their predictions.

PRECAUTIONS:

The clarity of the relationships between weather factors depends on locality, season, and type of weather conditions. A stagnant situation, in which pressure patterns remain nearly fixed day after day, produces little change in weather and thus, relationships are almost impossible to detect. This is why it is important for students to look first at the period of time during which marked changes have taken place.

TYPICAL RESULTS:

If data have been collected over a period of at least 2 months, there should be a number of weeks during which marked changes in weather took place and students should be able to clearly establish relationships between changes in pressure, wind direction, changes in temperature, cloudiness, and precipitation.

MODIFICATIONS:

1. Have some of the students carry out a statistical investigation of the weather factor relationships. A good description of how to do this is given in *Investigating the Earth*, Teacher's Guide, pp. 234-235.

2. Capitalize on student ability to make predictions by having them make daily forecasts for the local school district. Encourage them to keep a record of their successes and to analyze any failures carefully so that future mistakes can be avoided or reduced.
3. If for some reason, a weather watch has not been maintained, this investigation can be done by using "canned" data taken from previous years, newspapers, or U.S. weather bureau data. (Order the *Local Climatological Report* for your nearest weather bureau station.)
4. Exchange weather watch data with other schools in the State and/or Nation. Analyze any similarities and differences.

REFERENCES:

Investigating the Earth, p. 193; Teacher's Guide, pp. 232-237, 253.
Our Planet in Space, pp. 226-233, 241-246, 248-249, 258-259, 264-274, 324-325.

VII-A-1a: WEATHER WATCH ANALYSIS
(Continuation of LTI #1, - Weather)

QUESTION:

What relationships between atmospheric variables can be determined from local observations?

INTRODUCTION:

In the weather watch, you have made and graphed daily observations of the more important weather variables. Since the beginning of the watch, you have learned many concepts that can now be applied to these weather factors. In this investigation, you will analyze the data for relationships between the various weather factors, and compare local data with U.S. weather maps for the same time period.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. determine which of the variables are related and whether the observed relationship is inverse or direct.
2. predict the effects of a change in one of the variables on the other variables.
3. summarize the events that usually precede precipitation.
4. summarize the events that usually precede fair weather.

METHOD:

1. Study the weather watch data carefully, especially those weeks during which marked changes occurred in the local weather.
2. List all factors that seem to be related and indicate whether the relationship is direct or inverse. Also, make an estimate of the strength of the relationship (whether it is: always true, sometimes true, or rarely true); you might express this in terms of the percentage probability.
3. Obtain U.S. weather maps for several of the weeks during which marked changes occurred in the local weather. Study the maps, and attempt to correlate them with your local data. Describe your observations.

4. Compare your findings with those of other students to determine areas of agreement and disagreement in your interpretations.
5. Obtain a sample set of data from the teacher. Describe a weather prediction for the next day. Check your prediction against what actually happened. Determine your accuracy. List some factors which could have made your prediction more accurate.

QUESTIONS:

- (A-1.11) 1. What frequency of occurrence would lead you to the identification of the existence of a relationship between two weather variables?
- (A-1.21) 2. What is the relationship between cloud cover and temperature?
- (A-1.31) 3. What is the relationship between air pressure and temperature?
- (A-1.41) 4. What is the relationship between dew point temperature and air temperature?
- (A-1.42) 5. As the difference between dew point temperature and air temperature decreases, what is the probability of precipitation?
- (A-1.51) 6. What is the relationship between wind speed and atmospheric pressure?
- (A-1.71) 7. How do other weather variables seem to be related?
 8. What weather events usually precede precipitation?
 9. What weather events usually precede clearing?

VII-B-1a: THE SYNOPTIC WEATHER MAP

QUESTION:

What air mass characteristics can be determined from synoptic observations?

MATERIALS:

Student handout sheets, U. S. Weather Map Series (weekly set for each group of students).

SUGGESTED APPROACH:

1. Initiate a discussion about the extension of observation of weather from the local area to an area of continental size. Relate the discussion to the lead question.
2. Students already should have developed some awareness of weather variables and how they are measured. In this investigation they will see how this information is used to present a "bird's eye view" of an entire weather system on a synoptic weather map and how this weather map can be used to make short-term predictions of future weather conditions.
3. Very little prelab discussion is necessary. Indicate to students that this is an exercise in the interpretation of various "fields," similar to the work done in an earlier topic. Indicate that irregularities, "anomalies," may be observed in the field patterns.
4. Some class time might be spent getting the students started. This will vary according to individual student ability.
5. During postlab discussion, develop the ideas that this synoptic weather map can be used to identify major weather patterns, such as: air masses, cyclones, anticyclones, interfaces between air masses (fronts), and areas of associated bad weather.
6. Have the students examine a series of daily U.S. weather maps and determine the speed and direction that weather systems move across the country.
7. Have students attempt short-range predictions.

TYPICAL RESULTS:

1. The student maps, when completed, should appear similar to those on Supplementary Sheets #2 and #3.
2. The students should be able to realize from viewing their three completed maps that "some kind of irregularity" exists in the same location on all three maps (i.e., northerly trending isotherms, sharp "V's" in isobars, and abrupt changes in wind direction).
3. The students should make the following observations and inferences from a study of their maps. This may be summarized and reviewed in postlab session.

Map I - Barometric Pressure:

- (1) Uniform HIGH pressure area over the Utah area; another over Miami.
- (2) LOW center near Cincinnati.

- (3) Isobars develop a "V" pattern resembling a gully or trough from Galveston to Cincinnati and from Hatteras to Cincinnati. Isobars change direction abruptly in these regions.

- (4) Pattern around the Low is not as circular as around the High.

Map II - Surface Wind Patterns:

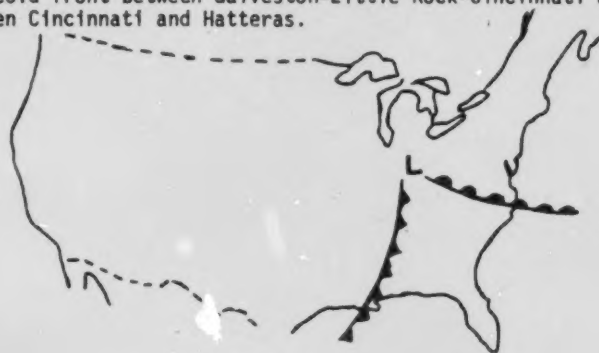
- (1) A definite streamline pattern is observable.
- (2) Air appears to be converging on the Cincinnati area, approaching in a somewhat counterclockwise pattern.
- (3) Air appears to be diverging from the Utah (Salt Lake City) area in a somewhat clockwise pattern.
- (4) An abrupt change in wind directions appears in the Galveston-Little Rock-Cincinnati region.

Map III - Surface Temperature Patterns:

- (1) Large temperature change (steep gradient) near Richmond-Hatteras.
- (2) N-S isotherm in Galveston-Little Rock-Cincinnati area.
- (3) General trend toward cooler temperatures inland, warmer temperatures along coastline, typical of late fall or early spring.

Map IV-- Sky Conditions and Precipitation Patterns:

- (1) Precipitation is occurring in an observable area between Galveston-Little Rock-Cincinnati and Richmond-Hatteras.
- (2) Generally cloudy skies prevail in adjacent areas.
- (3) The Salt Lake City area and the southwest are clear.
- (4) Inferences drawn from the temperature, pressure, and wind anomalies, coupled with locations of precipitation areas, lead to the identification of a cold front between Galveston-Little Rock-Cincinnati and a warm front between Cincinnati and Hatteras.



MODIFICATIONS:

1. The teacher may wish to have the students analyze the completed maps (i.e., reproduce Supplementary Sheets #3 and #4 for student use) and not become involved with drawing their own.
2. The teacher may wish to use data from a more current weather map and relate it to the weather the student is now experiencing.

REFERENCES:

Investigating the Earth, pp. 193-202; *Teacher's Guide*, pp. 235-247.

VII-B-1a: THE SYNOPTIC WEATHER MAP

QUESTION

What airmass characteristics can be determined from synoptic observations?

INTRODUCTION:

We experience a great variety of weather conditions in the area where we live as we carry on our daily lives. How are these weather events associated with those occurring elsewhere in the country? One of the best ways to look at a large system, when we are capable of directly viewing only a very small part of it, is to observe a model.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. plot weather data on a blank map and construct an isoline model for appropriate variables.
2. identify major weather patterns, such as airmasses, cyclones, anticyclones, fronts, and storm areas if they exist on a weather map.
3. make short-range weather forecasts when provided with a series of daily weather maps.

METHOD:

PART I

1. Label your four maps as follows: Map I - Barometric Pressure Patterns; Map II - Surface Wind Patterns; Map III - Surface Temperature Patterns; Map IV - Sky Conditions and Precipitation Patterns. Use the information plotted on the base map to draw each individual map as indicated below.
2. On Map I, draw equal barometric pressure lines (isobars). Use a 4 millibar interval between lines, starting with 100.0 millibars. If any major irregularities in the lines appear, do not alter them.
3. On Map II, draw a short arrow through each circle indicating the direction of wind movement at that city. Draw streamlines (longer arrows representing the direction air would move) for the general map area. Do not smooth out any abrupt changes.

4. On Map III, lightly sketch in equal temperature lines (isotherms), using a 5 degree interval between lines. When you are satisfied that the lines are correct, darken them with pencil or ink. The lines should follow the measured temperatures with a minimum amount of "interpreted" variations. Irregularities should not be smoothed out!
5. On Map IV, draw a boundary line enclosing the partly cloudy area and draw vertical lines throughout the area. Draw a line enclosing the cloudy or foggy area and crosshatch the entire area. Draw a line enclosing the area where it is raining, and shade the area with your pencil.
6. Examine the four maps carefully and compare them to each other. Describe the patterns that you are able to observe.

PART II

7. Examine a series of U.S. daily weather maps. Try to locate well-defined "Highs" and "Lows." On a blank map of the United States, draw small circles representing the daily positions of a "High" as it moves across the United States. Label the interior of each circle with an (H) and connect them with a smooth dotted line representing the apparent path of this system. Repeat the procedure, using small squares, for the "Low" pressures.
8. Observe the general direction of movement of these systems across the country, and, using the scale of the map, calculate the average number of miles per day that the systems move.
9. Examine the first two or three daily maps in a series (not the same series used previously), and write a weather forecast for your area for the next 2 days. When completed, turn to the next two maps of the series and check the accuracy of your prediction.

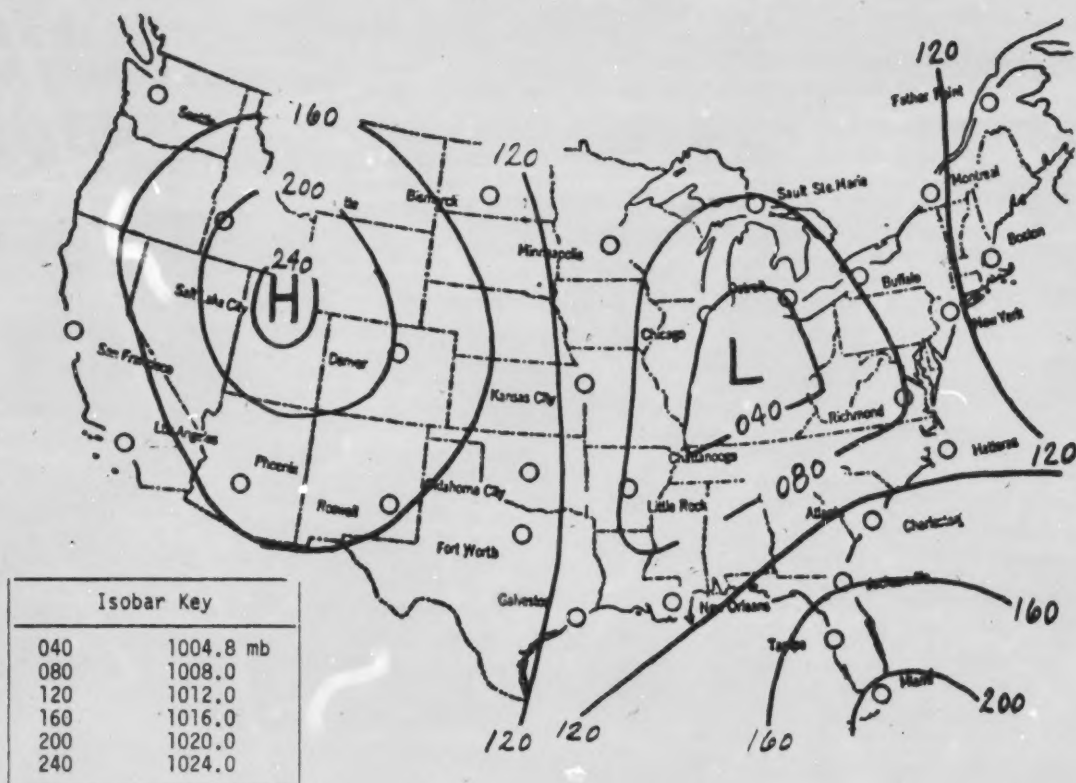
QUESTIONS:

1. What characteristics can be used to identify the airmasses on your map?
- (B-1.12) 2. What are the characteristics of the temperature field within the airmasses?
- (B-1.13) 3. What is the pattern of air movement (wind direction) in the airmass located in the east?
- (B-1.14) 4. What is the pattern of air movement (wind direction) in the airmass located in the west?

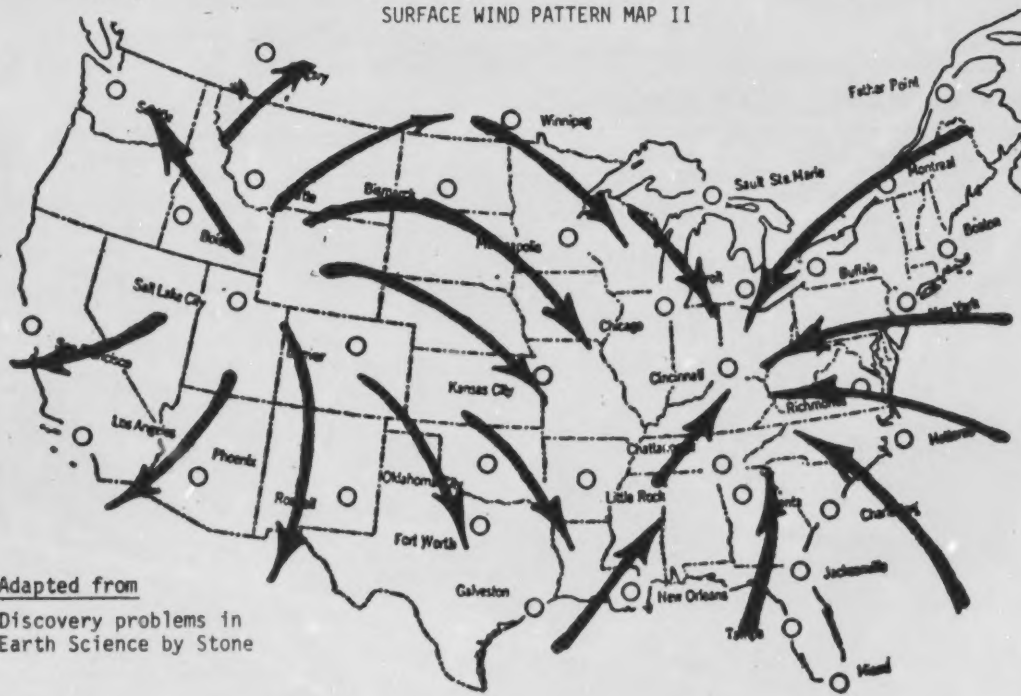
- (B-1.15) 5. With respect to the position of major airmasses, where is precipitation occurring?
- (B-1.16) 6. With respect to the airmasses, where are the atmospheric conditions most likely unstable?
- (B-1.31) 7. What is the average rate and direction of movement of an air mass across the U.S.? How could this information be used for weather forecasting?
- (B-1.21) 8. How do the properties of the airmasses compare to their apparent point of origin?
9. All the surface air in the eastern part of the U.S. seems to be converging on one area. What happens to it once it gets there?
10. The surface air in the western part of the U.S. seems to be moving out of one area. Where is the air to replace it coming from?
11. Observe the way the isotherms bend on your temperature maps as they cross from water to land. Which is warmer, the land or the water? What time of the year would you infer this to be? Explain.



ATMOSPHERIC PRESSURE MAP I



SURFACE WIND PATTERN MAP II

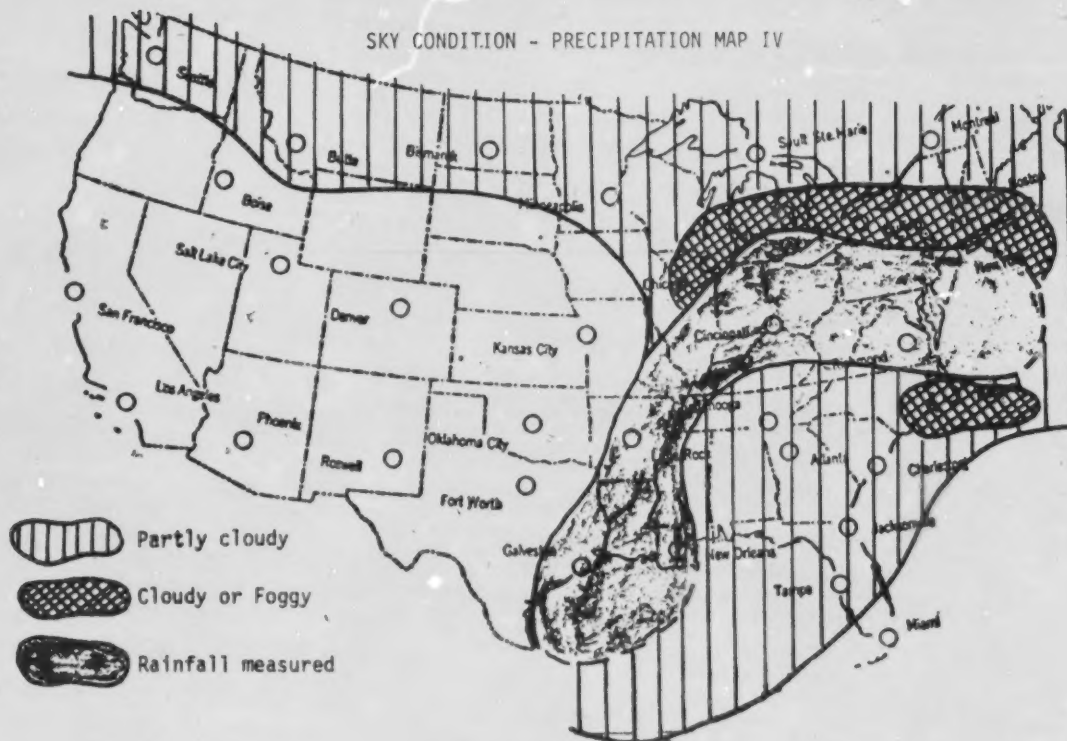


Adapted from
Discovery problems in
Earth Science by Stone

SURFACE TEMPERATURE MAP III



SKY CONDITION - PRECIPITATION MAP IV



VII-C-1a: EVAPORATION

QUESTION:

How does the atmosphere acquire moisture and energy?

MATERIALS:

The needs will depend entirely on the procedures designed by the students. A variety of beakers, petri dishes, thermometers, heat lamps, meter sticks, balances, fan, etc. will probably be requested. Suggest that any unusual items be brought in by the students or requested well in advance of class.

SUGGESTED APPROACH:

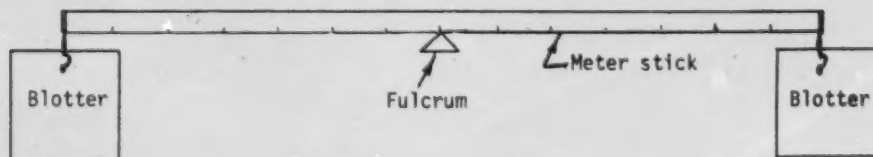
1. Have the students consider the question, "What factors affect the rate of evaporation?" Make a list of their suggestions; the list should include surface area exposed to air, movement of air, water temperature, humidity of air, air temperature. Assign one factor to each student or small group of students.
2. Instruct students to design a procedure that will test the effect of their factor on the rate of evaporation. Remind them that they are making models of the earth's atmospheric engine and that realistic temperature ranges, wind speeds, etc., should be used. Discuss with them the necessity for keeping all variables constant, except the one being studied.
3. Have students carry out their procedures. This can be done either in class or at home.
4. Lead the students in a discussion of their procedures, data, and interpretations. Help them to explain the reasons behind each of the effects.

PRECAUTIONS:

1. If you expect the investigation to be completed during one class period, complete steps one and two during the preceding class or as homework.
2. Commercial evaporation kits use sponges which are very difficult to cut into identical pieces. Also, some of the plastic balances melt when a heat lamp is used as a heat source. Simple wooden balances, constructed from meter sticks, or triple beam balances can be used in place of the plastic balances. Paper blotter materials cut into 6 or 8 inch squares can be used in place of the sponges.

TYPICAL RESULTS:

The students may design apparatus similar to that in the diagram below:

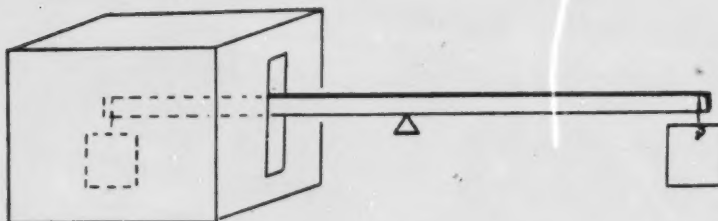


Possible techniques for usage are:

- 1) Surface Area - Cut four equal-sized blotters; dip each in a container of water.

Hang two blotters, one suspended below the other on one end of the balance. On the other end, hang two blotters positioned back to back so that only two sides are exposed to the air. Adjust the fulcrum until a balance is obtained. Observe over a period of time, and determine which way the balance tips. The side that goes up will be the one with the greater evaporation.

- 2) Air Movement - Balance identical, soaked blotters on the ends of the meter stick. Adjust a fan so that it blows air past only one of the blotters. Observe the results.
- 3) Water Temperature - Dip one blotter in hot water, the other in cold. Set up the apparatus and observe the results
- 4) Air Temperature - Balance identical, soaked blotters on the meter stick. Direct a light bulb toward one and observe.
- 5) Humidity - Cut a 1-inch slot in the side of an approximately 1-foot cube cardboard box. (See diagram.) Moisten the interior walls of the box, and position the balance so that one end extends through the slot. Close the box top and observe.



REFERENCES:

Our Planet in Space, pp. 261-262.
Investigating the Earth, p. 181; *Teacher's Guide*, pp. 223-225.

VII-C-1a: EVAPORATION

QUESTION:

How does the atmosphere acquire moisture and energy?

INTRODUCTION:

What makes water evaporate? What factors affect the rate of evaporation? In this investigation, you will design your own experiment to test the effects of these factors on the evaporation rate.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. describe a group of variables that would effect rate of evaporation.
2. design a procedure that can be used to test the effect of each factor on rate of evaporation.
3. carry out the designed procedure, collect data, and report the discovered effect on evaporation rate.
4. compare your data with that of students working with the same factor.
5. discuss the effects of the other factors with students working with them.

QUESTIONS:

- (C-1.11) 1. How can water get into the atmosphere?
- (C-1.23) 2. What is the effect of each of the factors that were investigated on the evaporation rate of equal volumes of water?
- (C-1.13) 3. What is the relationship between energy and evaporation?
- (C-1.13)
(C-1.23) 4. What would be the characteristics of a good drying day (rapid evaporation)?

VII-C-1b: VAPOR PRESSURE

QUESTION:

How does the atmosphere acquire moisture and energy?

MATERIALS:

One set of apparatus as shown on the student sheet for each group of three students, food coloring.

SUGGESTED APPROACH:

1. Discuss with students the concept of vapor pressure and how it could be investigated.
2. Suggest the use of this apparatus although other approaches might be used.
3. Have the students determine the relative vapor pressures of water at various temperatures. (Temperatures above or below room temperature can be achieved by placing the bottle in a hot water or ice bath and allowing a few minutes for the bottle to adjust to the temperature of the bath.)

PRECAUTIONS:

1. The ends of the glass tubing must be reduced to a small diameter (about 0.5 mm., see detail drawing) in order for the apparatus to work properly.
2. The glass tubing should be well supported to reduce the possibility of breakage.
3. Be sure to use a dry bottle for each trial; wiping will not dry the bottles enough they must be allowed to stand open for several hours in sunlight or must be heated to drive off the moisture.
4. The amount of vapor pressure that can be observed will depend on the vapor pressure in the room (i.e., with high room humidity, little change in vapor pressure will be observed).

TYPICAL RESULTS:

1. Students should see the water level (vapor pressure) rise rapidly and then level off as saturation is approached.
2. A higher temperature environment (i.e., a warm water bath) should result in higher leveling-off point (i.e., higher saturation vapor pressure).

MODIFICATIONS:

1. Use this exercise as a teacher demonstration.
2. Have a small group of students do the exercise as a demonstration.

VII-C-1b: VAPOR PRESSURE

QUESTION:

How does the atmosphere acquire moisture and energy?

INTRODUCTION:

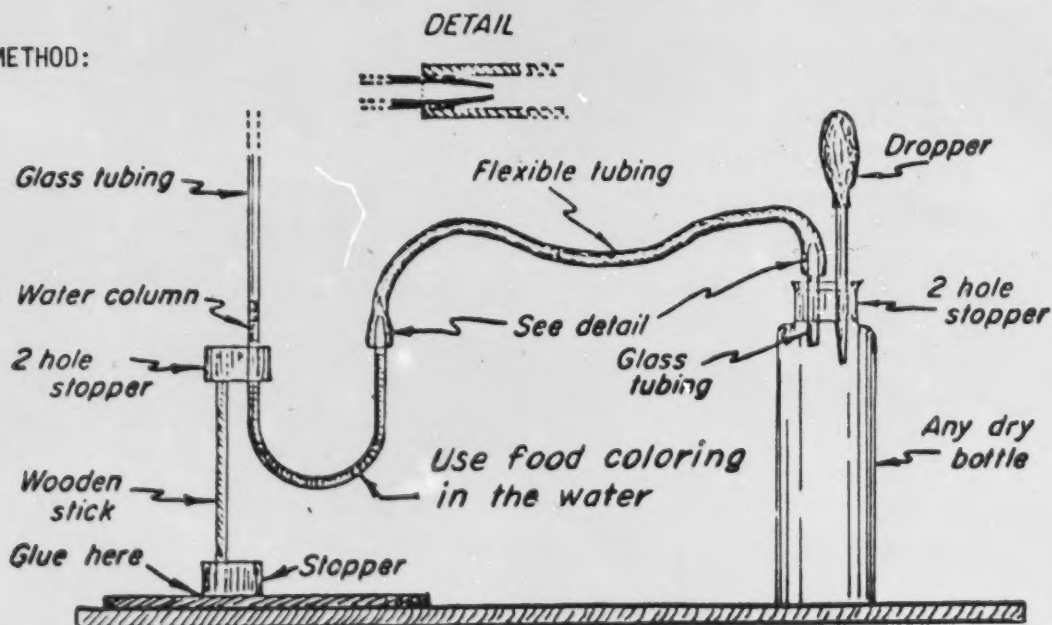
Vapor pressure is that part of air pressure that is caused by water vapor in the air. As water evaporates, the number of molecules of water per unit volume of space increases, and this exerts a greater pressure. (If the water reaches the maximum number per unit volume, saturation vapor pressure exists.) How will the rate of evaporation change as the vapor pressure increases? What factors affect the saturation vapor pressure?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. measure the relative saturation vapor pressure for a given set of conditions using the apparatus provided.
2. describe the relationship between saturation vapor pressure and temperature.
3. identify similarities and differences between the experimental model and the earth's atmosphere.

METHOD:



1. Set up the apparatus as shown in the diagram.
2. Place a metric scale behind the glass tube so that readings can be made as the water level changes.
3. Remove the dropper, fill it with water, insert it in the stopper and measure and record the height of the water level.
4. Squeeze the water into the bottle.
5. Take readings of the water level every 10 seconds and record on a data table.
6. Place another dry bottle on the apparatus, and position it in a warm water bath. Repeat the procedure.
7. Place another dry bottle in an ice bath and repeat.
8. Graph the data for each exercise.

QUESTIONS:

1. Why does the water column rise? Is the column being pulled or pushed? By what? How do you know?
2. What is the pattern of change in the water levels with time?
- (C-1.21) 3. In an air-water environment (e.g., air over a lake), where would you expect the vapor pressure to be highest?
- (C-1.22) 4. Describe the relationship between the vapor pressure and the rate at which evaporation occurs.
- (C-1.32) 5. Describe the relationship between saturation vapor pressure and air temperature.
- (C-1.32)
(C-1.41) 6. What would be the probable pattern of the average saturation vapor pressure between the equator and the poles?

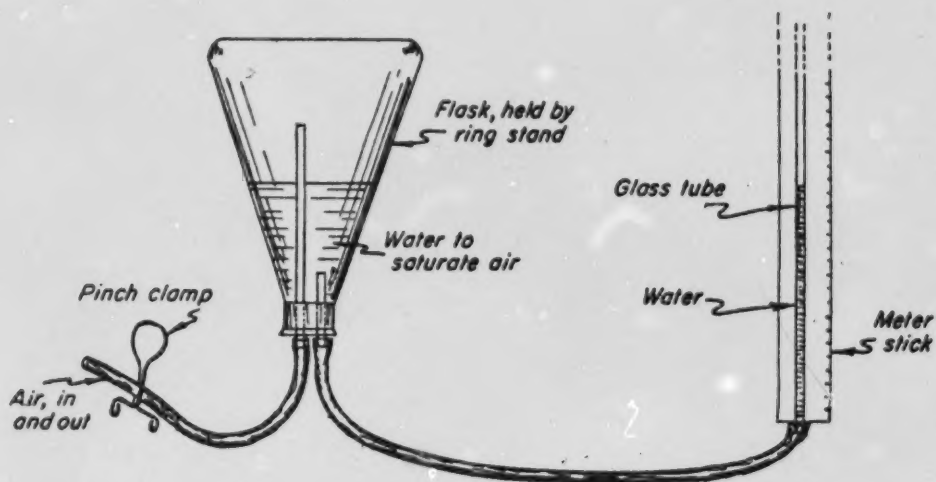
VII-C-3a: ADIABATIC COOLING AND CLOUD FORMATION

QUESTION:

How are moisture and energy released within the atmosphere?

PURPOSE:

The formation of clouds requires saturated moist air and a condensation surface. Saturation is achieved when the air is cooled adiabatically by decreasing the pressure and allowing it to expand (adiabatic process). Condensation surfaces, or nuclei, are usually particles of dust, smoke, salt, pollen, etc. This demonstration can be used to show that a cloud results only when both condensation nuclei and reduced pressure are present.



PROCEDURE:

1. Set up the apparatus as shown in the diagram. Force air into the flask until the water in the glass tube is to the top of the meter stick. Close the pinch clamp.
2. Open the pinch clamp suddenly. Observe the pressure drop as shown by the decreasing water level in the glass tube. Observe the air in the flask (no cloud should form).
3. Open the flask and allow some smoke from a candle to enter. Close the flask, return it to its original position and force the water level in the tube to the top of the meter stick. Close the pinch clamp.
4. Open the pinch clamp suddenly. Observe the pressure and the air in the flask (pressure falls, a cloud forms).

PRECAUTIONS:

1. Swirl the water in the flask before carrying out the demonstration. This is necessary to saturate the air with water vapor.
2. A black card behind the flask will make the cloud more visible.

MODIFICATIONS:

1. If possible, introduce a thermometer into the flask in such a way that its bulb is in the air. This would allow you to measure the temperature change that results from the pressure changes and actually prove that cooling occurs.
2. To show that air expands when pressure decreases, blow a little air into a small balloon and tie it shut. Place the balloon inside a bell jar. Evacuate the bell jar with a suction pump. Watch the balloon expand.
3. To illustrate the cooling of air as it expands under decreased pressure, inflate an inner tube to a high pressure. Let it rest for about 15 minutes so that its temperature will become equal to the room temperature. Measure room temperature. Open the valve of the inner tube and measure the temperature of the escaping air.
4. Obtain a large, strong bottle. Put half an inch of water in the bottle and seal the bottle tightly. Insert a glass tube through a hole in the stopper, and connect the glass tube to a bicycle pump by means of rubber tubing. Pump air into the bottle until moderate pressure is built up. Clamp the tube to prevent the escape of air and to retain the pressure. Allow the bottle to stand for several minutes until the air in the bottle is saturated with water vapor. Release the pressure suddenly by opening the clamp. Watch the cloud form in the bottle.

QUESTIONS:

1. Why does the water in the glass tube fall when the pinch clamp is opened?
2. Why didn't a cloud form the first time?
- (C-2.31) 3. What must be happening to the air in the flask when the pinch clamp is suddenly opened? What is the evidence?
- (C-3.11) 4. What conditions seem to be necessary for the formation of clouds?
- (C-3.21) 5. Describe the composition of a typical cloud droplet.

REFERENCES:

Investigating the Earth, pp. 184-190; Teacher's Guide, pp. 226-230, 250-252.
Our Planet in Space, pp. 269-275, 288-291.
What Makes Clouds Form? EBF-AGI.

VII-C-3b: DEW POINT - CUMULUS CLOUD FORMATION

QUESTION:

How are moisture and energy released within the atmosphere?

MATERIALS:

Shiny metal can, sling psychrometer, thermometer, crushed ice, water.

SUGGESTED APPROACH:

1. Briefly discuss with the students what conditions are necessary for cloud formation. Remind them that cumulus clouds form from rising air and ask them what information they would have to know to be able to calculate the base altitude for such clouds.
2. Have the students measure the dew point directly by determining the temperature at which condensation first appears on the outside of a metal can containing water and crushed ice. They should repeat this measurement several times and average their results.
3. Have the students measure dew point indirectly by using a sling psychrometer and a dew point temperature chart such as the one on the Earth Science Reference Tables.
4. Have the students plot the surface air temperature on the temperature vs. altitude graph. (See Supplemental Sheet.) The fact that rising air cools at the rate of $10^{\circ}\text{C}/\text{km}$. will determine the temperature of the air at 1 km. A line through these points will show the temperature of rising air at any altitude.
5. Have the students plot the observed dew point on the temperature vs. altitude graph. Since the dew point decreases at a rate of $2^{\circ}\text{C}/\text{km}$., the dew point at 1 km. can be determined. A line through these points will show the dew point at any altitude.
6. The point at which these two lines cross determines the altitude at which the dew point is equal to the air temperature and where the base of the cumulus cloud would be.
7. Call the U. S. weather bureau for the official dew point, cloud height, and air temperature.
8. Lead the students in a brief discussion of their data relative to the official value of the weather bureau. Analyze any apparent sources of error.
9. Discuss why both air temperature and dew point temperature decrease with altitude.

PRECAUTIONS:

1. If the students add ice to the water too quickly, the value they obtain for the dew point will be too low since the temperature will fall past the dew point too quickly.
2. Try to carry out the investigation on a day when there are fair-weather cumulus clouds. If there are no clouds or the "wrong" kind of clouds, use the data to predict the height at which clouds would form if all the necessary conditions were met. Since this investigation will be done during the winter months, this situation is very likely to occur.
3. Try to do the investigation outdoors on a day when the dew point is above 0°C .

TYPICAL RESULTS:

If outdoor data are used, students should be able to predict cloud base height to within a few hundred meters. If the investigation is done indoors, it will help if the windows are opened wide previous to class and kept open during class. Indoor data produce variable results.

MODIFICATIONS:

Have the students use the wet adiabatic rate ($6^{\circ}\text{C}/\text{km.}$), above the intersection of the air temperature-dew point lines, to find out at what altitude the clouds would be composed of ice crystals.

REFERENCES:

Investigating the Earth, pp. 184-187, 200, 574; *Teacher's Guide*, pp. 226-229, 242-244.
Our Planet in Space, 262-263, 268-269, 288-291.
The Earth Sciences, pp. 250-252.

VII-C-3b: DEW POINT - CUMULUS CLOUD FORMATION

QUESTION:

How are moisture and energy released within the atmosphere?

INTRODUCTION:

Have you seen the sky filled with cumulus clouds and noticed that their flat bases all seem to be the same distance from the ground? The water droplets that form these clouds come from the cooling of warm, moisture-laden air as it rises from the ground. Why do the clouds begin to form at the same level? What must be true about the temperature at that level? In this investigation, you will measure the air temperature and dew point, and use these temperatures to determine the height at which cumulus clouds would form in the sky above you.

OBJECTIVES:

When you have finished this investigation, you should be able to:

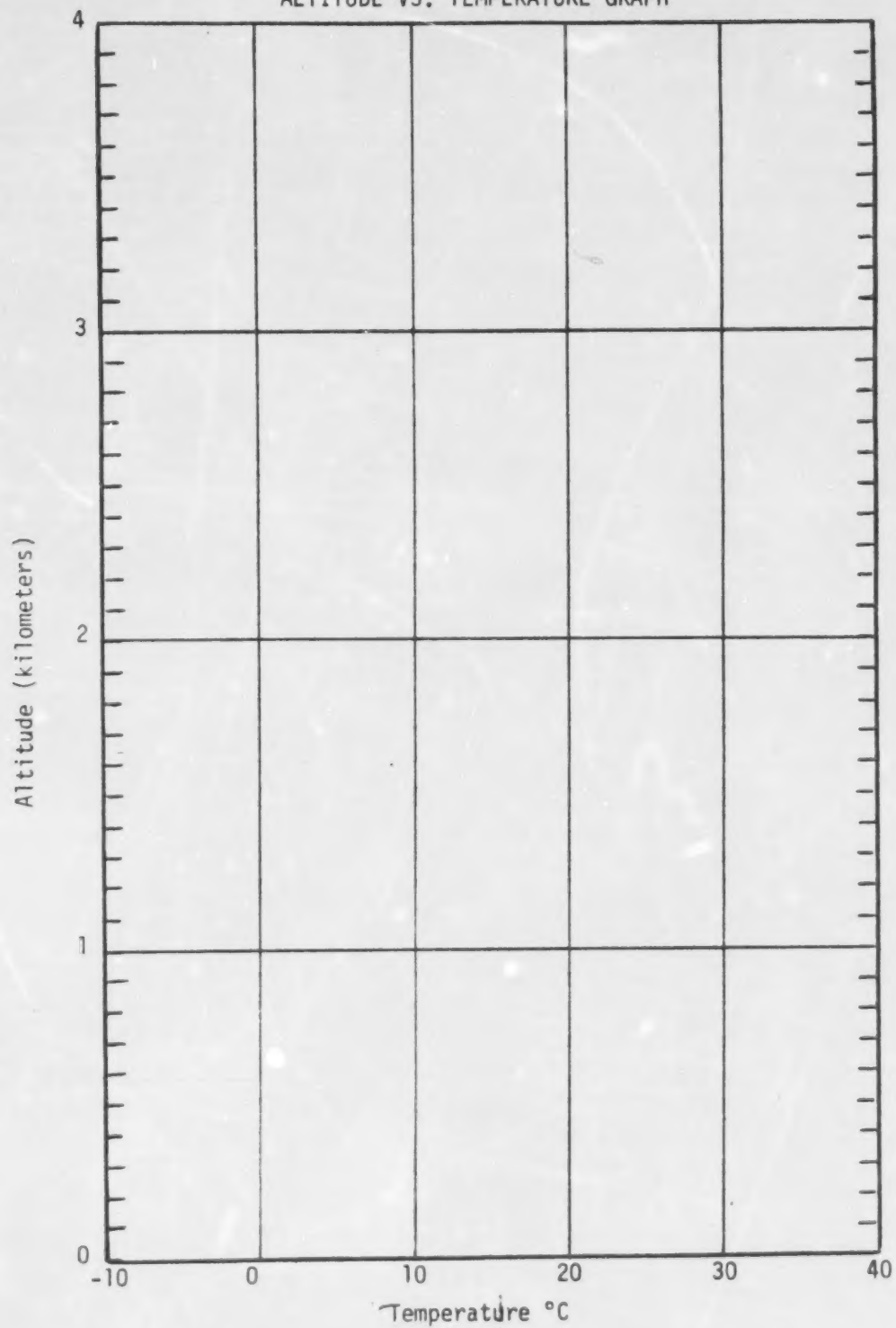
1. determine the dew point temperature using the psychrometer and shiny can methods.
2. determine the base altitude of cumulus clouds from dew point and air temperature data.
3. measure and record the dew point temperature indirectly by using a sling psychrometer and the dew point temperature chart in your Earth Science Reference Tables.
4. compare your data with those of other students to determine variations.
5. find the base height at which cumulus clouds begin to form by plotting your dew point and temperature data on the supplementary sheet provided.
6. compare your base height determination with the official weather bureau value and analyze the reasons for any differences.

QUESTIONS:

- (C-3.11) 1. Why does water vapor condense at the dew point temperature?
2. How do your values for dew point temperature obtained from the can compare with those from the sling psychrometer? If they were different, what could be the reason(s)?

- (C-1.31) 3. What would be the relationship between evaporation and condensation when the air is saturated? (Saturation vapor pressure.)
- (C-3.11) 4. Describe what happens when the dry adiabatic cooling curve and the dew point lowering curve meet, providing condensation nuclei are present.
- 5. Why does the base altitude of fair-weather cumulus clouds change from day to day?
- 6. What would happen to the air temperature and dew point temperature of descending air?

ALTITUDE VS. TEMPERATURE GRAPH



VII-C-4a: AIR-WATER INTERACTION

QUESTION:

How are moisture and energy released from the atmosphere?

MATERIALS:

World wind map and world ocean current map (supplementary sheet).

SUGGESTED APPROACH:

1. Briefly discuss with students the cause of wind. Ask them to suggest a few effects wind may have on the earth's surface, and have them briefly trace the energy transfers which are prerequisites to these effects.
2. The remainder of this exercise can best be accomplished as a homework assignment.
 - A. Have the students compare the world wind and ocean current maps for similarities and differences.
 - B. Have the students examine some local effects of wind which indicate a transfer or release of energy from the atmosphere to the earth's surface. Some possibilities are:
 - 1) Attach about four balloons to a flag pole at various heights. Normally the balloons will indicate faster air movement near the top than near the ground, due to friction of the air with the ground. It will also be apparent that friction turns winds.
 - 2) Observe "tree flags." Most trees have longer limbs on one side than on the other, and this shows the direction of the prevailing wind.
 - 3) Observe waves on a body of water. Observe wind direction and relate it to the direction of the wave movement.
 - 4) Observe an area of sand; carefully locate any ripple marks or dunes. At the same time, observe wind direction. Keep records for several days, note any changes in the location of the ripple marks or dunes and relate these to the wind. (The same results can be seen observing snow.)
3. After completion of the assignment, lead the students in a discussion of the observed wind effects; help them relate these to energy transfer and trace the path of this transfer.

REFERENCES:

Investigating the Earth, pp. 164-172, 234-240; Teacher's Guide, pp. 206-209, 218-219.
Our Planet in Space, pp. 226-232, 235-237, 313-317, 309-310, 419-434.
Exploring Earth Sciences, pp. 66-67, 107, 298, 378.
Focus on Earth Science, pp. 182-187, 230, 306-313.

VII-C-4a: AIR-WATER INTERACTION

QUESTION:

How are moisture and energy released from the atmosphere?

INTRODUCTION:

Man's development has been closely associated with wind. For example, anthropologists have been able to trace man's migration patterns from one land mass to another by observing the paths that crude sailing vessels follow.

The effects of wind on man have not all been positive. Hurricanes and tornadoes cause property damage and may result in human death.

What causes the wind? Where does the energy to move the air come from? What are the effects of this energy on the earth?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. cite several evidences of the release or transfer of energy from the atmosphere to the earth's surface.
2. analyze such release or transfer in terms of kinetic and potential energy and the conservation of energy.

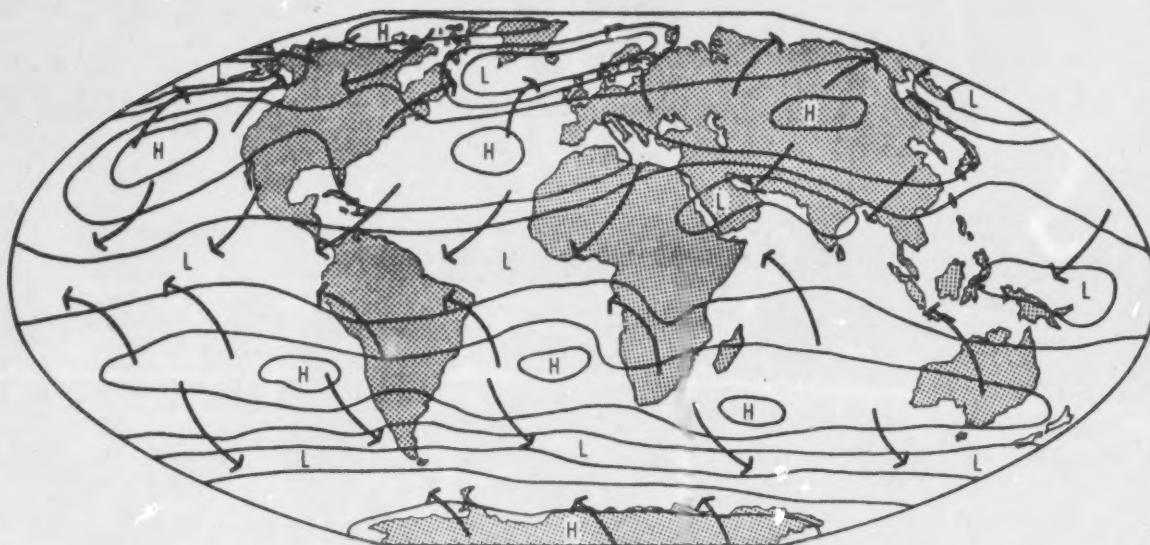
METHOD:

1. Compare the map of worldwide winds with the map of worldwide ocean currents and describe the probable associations between them.
2. Observe the effects of wind on objects in your local environment; find some effects that you think are caused by wind; then observe the wind's direction and see if any correlation is evident.
3. Discuss your findings with other students.

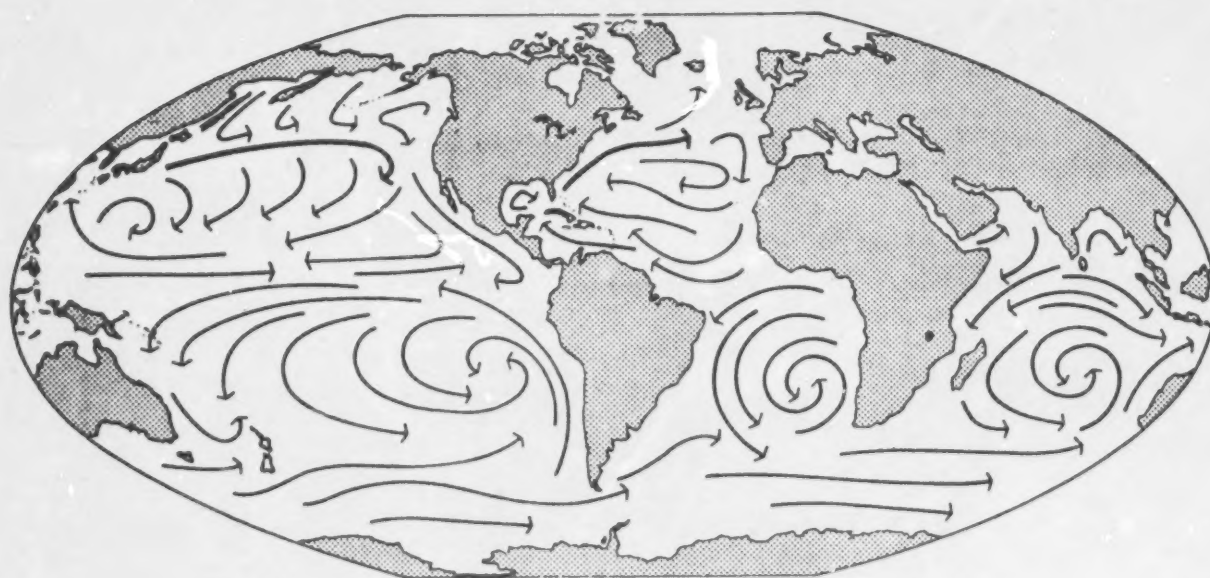
QUESTIONS:

1. What wind effects were you able to observe?
2. How did you know they were due to the wind?
- (C-4.21) 3. Choose at least one of your "effects," and describe the energy transfers that took place, identifying both those that were potential and kinetic energy.

SUPPLEMENTARY SHEET
(Wind Patterns - Ocean Currents)



Generalized Wind Pattern Map



Generalized Ocean Current Map

ADAPTED FROM:

Investigating the Earth, Teacher's Guide

t o p i c V I I I

TOPIC VIII - MOISTURE AND ENERGY BUDGETS AND ENVIRONMENT CHANGE

What Happens To Water And Energy

Released From The Atmosphere?

Time Emphasis: 11 days

	INVESTIGATION	A-1a	A-3a	A-3b	B-1a	B-2a	C-1a	LTI - #15	FE - #3	FE - #5										
	Estimated Time (Periods)	2	1	1	3	2	3													
TOPIC OUTLINE	A. Earth's water																			
	A-1 Ground water																			
	A-1.1 Infiltration	A-1.11																		
	A-1.2 Permeability	A-1.12																		
	A-1.3 Porosity	A-1.21																		
	A-1.4 Capillarity	A-1.22																		
	A-2 Surface water	A-1.31																		
	A-2.1 Runoff	A-1.41																		
	A-3 Pollution of the earth's water																			
	A-3.1 Sources of pollutants	A-2.11																		
	A-3.2 Types of pollutants	A-3.11																		
	A-3.3 Concentration of pollutants	A-3.21																		
	A-3.4 Long-range effects	A-3.22																		
	B. The local water budget	A-3.31																		
	B-1 Water budget variables	A-3.32																		
	B-1.1 Precipitation (P)	A-3.33																		
	B-1.2 Potential evapo-transpiration (Ep)	A-3.41																		
	B-1.3 Moisture storage (St)	A-3.42																		
	B-1.4 Moisture utilization																			
	B-1.5 Moisture deficit (D)																			
	B-1.6 Moisture recharge																			
	B-1.7 Moisture surplus (S)																			
	B-2 Streams																			
	B-2.1 Stream discharge and the water budget																			
	B-3 Climates and the local water budget																			
	B-3.1 Climatic regions																			

TOPIC VIII - MOISTURE AND ENERGY BUDGETS AND ENVIRONMENT CHANGE continued

TOPIC OUTLINE	INVESTIGATION		A-1a	A-3a	A-3b	B-1a	B-2a	C-1a	LII - #15	FE - #3	FE - #5								
	Estimated Time (Periods)		2	1	1	3	2	3											
C. Climate pattern factors C-1 Factors			What Factors Affect Climate Patterns?																
	C-1.1 Latitude	C-1.11																	
	C-1.2 Elevation	C-1.21																	
	C-1.3 Large bodies of water and ocean currents	C-1.31																	
		C-1.32																	
	C-1.4 Mountain barriers	C-1.41																	
	C-1.5 Wind belts	C-1.51																	
	C-1.6 Storm tracks	C-1.61																	
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1																	
	Measurement Skill	PIO-2																	
	Creating Models	PIO-3																	
	Analysis of Error	PIO-4																	
	Data Analysis	PIO-5																	
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Soil Water Movement																
			Stream Pollution																
			Water Purification																
			The Local Water Budget																
			Stream Hydrograph																
			Climate of an Imaginary Continent																
			Soil Moisture																
			Stream																
			Beach																

VIII-A-1a: SOIL WATER MOVEMENT

QUESTION:

How does water move into the earth?

MATERIALS:

Ring stand and column clamp; plastic or glass column, at least 30 cm. long; column outlet with clamp fitting; wire screen in bottom of column; 100-ml. graduated cylinder; two 400-ml. beakers (larger, if available); sorted earth materials (sieved sand, gravel, etc.).

SUGGESTED APPROACH:

1. Keep prelab discussion brief. Review the hydrologic cycle, in general, and infiltration of water into soil, specifically.

The following questions can be raised:

- a) What factors control the amount of water that a soil can hold?
 - b) What factors control the rate at which water can seep into soil?
 - c) What factors control the amount of water retained in a soil after it is drained?
 - d) How does water move through soil?
 - e) What direction does water move through soil?
 - f) How could any or all of these factors be measured?
2. Have the students set up the apparatus, measure, and record data concerning each variable.
 3. Conduct class demonstrations as follows:
 - a) Place 100 ml. of loose soil consisting of a mixture of particle sizes in a plastic tube, and measure the amount of water necessary to just cover the upper surface of the particles.
 - b) Set up three plastic tubes each about 3/4 filled with different-sized particles (i.e., fine sand, coarse sand, and gravel). Submerge the bases of the tubes equidistant into beakers of water leaving the clamp open so that the water is in contact with the base of the soil column. Mark the level to which the water has risen, with a grease pencil, using 2-minute time intervals. Allow the students to measure and record these measurements during the class period. The apparatus can be left on display for days with a new mark being made on a once or twice per day basis. The rate of rise will decrease rapidly after the first half hour.
 4. Have the students graph their results and draw inferences from the graphs.

PRECAUTIONS:

1. Wet particles should be removed and tubes cleaned and dried before rerunning the investigation (push a paper towel wad through the tube with a long stick). If this is not done, allowances must be made for the water that is retained.
2. The larger the particles, the harder it is to estimate when the surface is just covered with water. Some approximating may be necessary.

3. No particle larger than $1/6$ of the column diameter will work effectively because of poor packing.

TYPICAL RESULTS:

Student results will be quite varied, but you should expect the following:

1. There should be enough class data to convince the students that porosity is relatively independent of grain size.
2. The smaller the particles, the slower the rate of infiltration (low permeability).
3. The smaller the particles, the higher the rate (and amount) of capillarity.
4. The smaller the particles, the greater the amount of water retained.

MODIFICATIONS:

1. Whenever possible use earth materials; when unavailable, use beads, shot, etc.
2. Three or four tubes with different grain size soils can be set up with the bases of the tubes submerged in water and left for a couple of days to show how high the capillary water will rise if given time.
3. Water retention in soils is related to the surface tension of water. To demonstrate this phenomena, the following demonstration can be done. Fill two new test tubes (make certain lips of the tubes are not scratched) to level full with water and ethyl alcohol. The tubes must be level full. Drop BB's from a height of 1 cm. into each tube, and count the number dropped before the liquid begins to overflow the test tube.

The higher surface tension in water should allow a considerably larger number of BB's to be dropped into the tube before overflow occurs.

REFERENCES:

Investigating the Earth, pp. 209-210; *Teacher's Guide*, pp. 258-260.
Ground Water in New York (1964).

VIII-A-1a: SOIL WATER MOVEMENT

QUESTION:

How does water move into the earth?

INTRODUCTION:

Have you ever seen water seeping or flowing from a hillside? How fast does ground water move through the pore spaces in earth materials? Can water move upward through soil? In this investigation you will find evidence to answer some of these questions and others by examining properties of earth materials that affect the flow of water through soil materials.

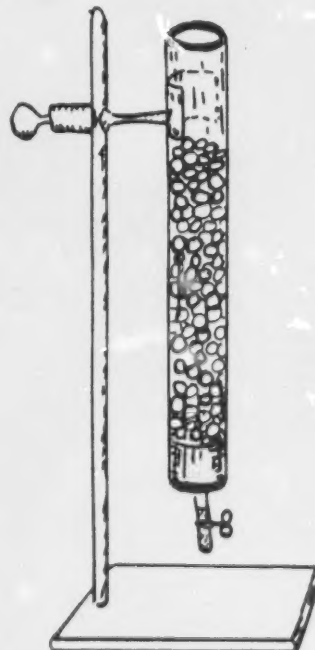
OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the effects of a change in soil particle size on each of the following:
 - a) porosity
 - b) permeability
 - c) water retention
 - d) capillarity

METHOD:

1. Set up the column as shown in the diagram. You will be provided with quantities of different sized particles. Place 100 ml. of one of the sized particles in the column, making sure that the wire screen is in place to prevent the particles from running out.
2. Measure and record the amount of water needed to just cover the upper surface of the particles and the time necessary for the wetting front to reach the bottom of the tube. This will provide a relative measure of the infiltration rate.
3. Open the clamp and allow the water to drain into a clean dry beaker. Remove the beaker when the flow is reduced to dripping, and measure the volume. Calculate the amount of water that was retained by the particles.



4. Repeat the procedure, using as many different-sized particles as you are directed to do.
5. Make observations and measurements of the demonstrations that your teacher has prepared for:
 - a) the amount of water necessary to just cover the upper surface of 100 ml. of a loose soil consisting of a mixture of particle sizes.
 - b) the rates of capillary action in three soils consisting of different but uniform particle sizes.
6. Prepare graphs of each variable observed (i.e., amount of water needed to fill the pore spaces, time necessary for infiltration, amount of water retained in the soil and capillary movement) vs. time. Examine your graphs and draw inferences from them.

QUESTIONS:

- (A-1.12) 1. What soil conditions are necessary for infiltration to occur?
- (A-1.21) 2. Describe the relationship between the permeability of soil material and its particle size.
- (A-1.22) 3. How far downward will a water molecule move after it infiltrated loose soil?
- (A-1.31) 4. What factors influence the porosity of soil material?
 5. Which soil particle size retains the greatest amount of water?
- (A-1.41) 6. What is the relationship between the capillarity and soil particle size?

VIII-A-3a: STREAM POLLUTION

QUESTION:

What is man's effect on the earth's water?

MATERIALS:

Student handout sheets, including supplementary map and graph sheet.

SUGGESTED APPROACH:

1. Conduct a class discussion concerning water pollution, considering the following topics:
 - a) How can you define water pollution?
 - b) What are some common pollutants found in water?
 - c) How could a study be conducted to determine the amount of water pollution existing in an area?
2. Assign the student handout sheets as a homework exercise (including the supplementary sheet).
3. After the students complete the exercise, conduct a brief concluding discussion during which you may want to consider the following:
 - a) There are natural forms of pollution as well as manmade forms.
 - b) Little can be done to prevent natural pollution, but to add to it unnecessarily is unjustifiable.

TYPICAL RESULTS:

1. Students should easily recognize the close correlation between quantity of dissolved solids in area streams and the bedrock types over which they flow.
2. They should recognize the sharp increase in dissolved solids on graph #1 as being a result of the Tonawanda Creek flowing across a boundary onto rock type B which is rich in dissolved solids.
3. Observations of graph #2 should result in the inference that the sharp increase in dissolved solids at Gowanda is most likely due to man's polluting the stream at that point since the stream flows over only one bedrock type.

BACKGROUND INFORMATION:

The total dissolved solids illustrated in graphs #1 and #2 include - SiO_2 , Ca, Mg, Na, K, HCO_3 , SO_4 , Cl, and NO_3 .

REFERENCES:

Erie-Niagara Basin, Chemical Quality of Streams, Basin Planning Report ENB-4, 1968, pp. 9, 29-32. Available from the State of New York Conservation Department, Water Resources Commission.

VIII-A-3a: STREAM POLLUTION

QUESTION:

What is man's effect on the earth's water?

INTRODUCTION:

Water pollution concern has increased greatly in recent years, probably due to the fact that increasing populations have greater needs for pure water. However, water pollution is not a new situation; in areas of high density population it has proven to be a problem through the ages. For example, one of the first recorded incidences, of large magnitude, occurred during the barbarian invasion of Rome during the fourth century A.D. The sewer system of Rome, clogged by silt and refuse, fell into ruin. Farmlands drained by the Cloaca Maxima reverted to a malarial swamp (the Pontine marshes). As a consequence, plagues and malaria debilitated thousands of Roman citizens when their services were needed to defend the Empire.

During the Civil War, water pollution probably resulted in deaths due to dysentery, typhoid, hepatitis, etc., and may have spelled the difference between victory and defeat in some crucial battles.

Long before man's existence, the environment was contaminated with natural undesirable ingredients. Examples of natural pollution might include dust, silt, volcanic products, and chemicals dissolved from rock and soil over which the water has passed. These forms of natural pollution are still in existence today and, with the addition of wastes by man, the problem is compounded.

OBJECTIVES:

When you have finished the investigation, you should be able to:

1. analyze maps and graphs of water quality data, and draw inferences concerning probable sources of pollution.

METHOD:

1. Study map #1, and make careful observations concerning: the area of New York State represented, the types of bedrock present and where they are exposed at the surface, the locations of Tonawanda and Cattaraugus creeks and the major population centers.
2. Compare map #2 with map #1 and draw inferences from your observations.
3. Observe graph #1, and compare it with map #1 Draw inferences

concerning the probable sources of the dissolved solids,

4. Observe graph #2 and compare it with map #1. Draw inferences concerning the probable sources of the dissolved solids.

QUESTIONS:

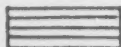
- (A-3.11) 1. What are the probable sources of the pollutants found in both creeks?
- (A-3.21) 2. What kinds of pollutants are studied in this investigation?
- (A-3.31) 3. Where are the greatest increases in the amount of pollutants in the streams observed?

VIII-A-3a

KEY



Rock A
Low solubility



Rock B
High solubility



Rock C
High solubility



Rock D
Low solubility

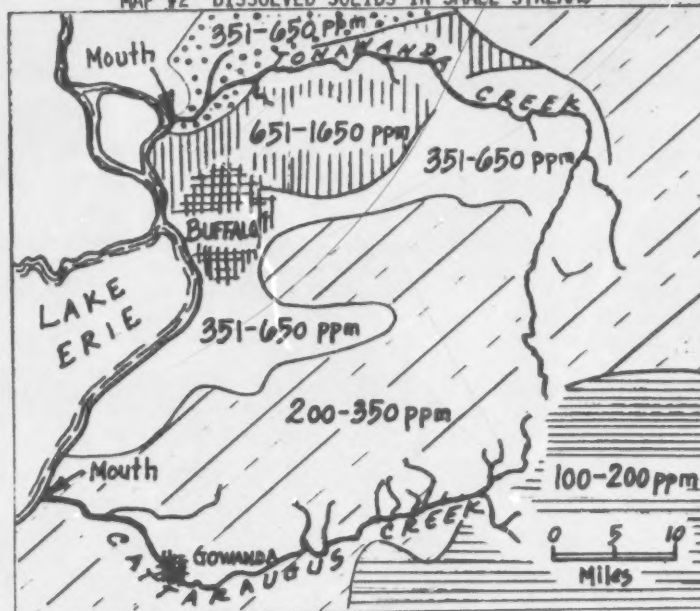


Rock E
Low solubility

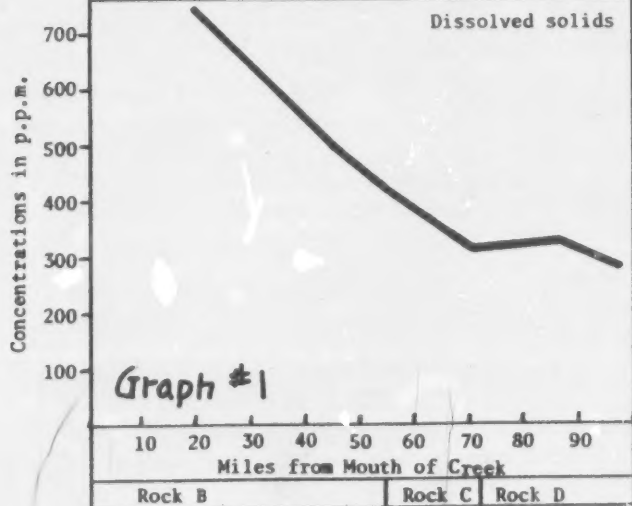
MAP #1 ROCK TYPES - WESTERN NEW YORK



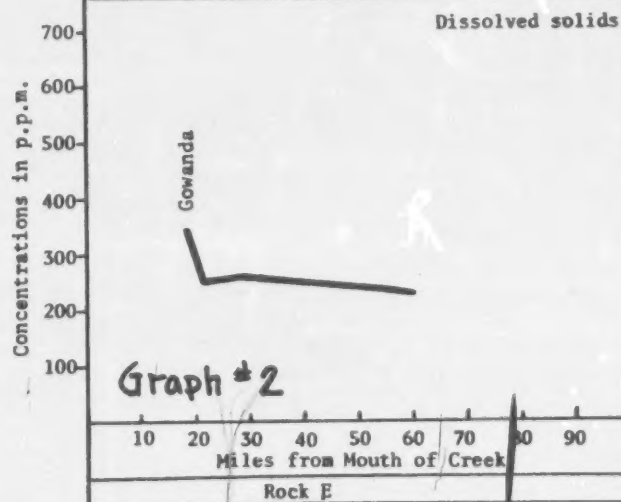
MAP #2 DISSOLVED SOLIDS IN SMALL STREAMS



TONAWANDA CREEK



CATTARAUGUS CREEK



VIII-A-3b: WATER PURIFICATION

QUESTION:

What is man's effect on the earth's water?

MATERIALS:

Large beaker, glass, or jar; muddy water (can be made from clay or soil and clear water); sodium bicarbonate; aluminum sulfate solution (most liquid deodorants and styptic pencils, used to stop bleeding from small cuts, contain aluminum sulfate).

SUGGESTED APPROACH:

1. Discuss with the students, problems in pure water shortages that exist today. Ask them to identify some solutions to these problems. Water recycling should be included in the discussion.
2. Discuss some of the problems faced in removing pollutants from water and making it usable for humans to drink.
3. Provide the necessary materials and have the students complete the laboratory part of the investigation.

PRECAUTIONS:

1. If the water is too muddy, it may take longer than a period to coagulate. It may be necessary to dilute the muddy water with some fresh water to speed up the process. You may want to find the right combination before the class tries the investigation.

TYPICAL RESULTS:

The muddy water should clear up in a matter of minutes after the chemicals have been added and stirring has taken place.

MODIFICATIONS:

1. Filtration and the purifying effect of biologic action can be demonstrated by using a large pipe. The pipe should be 4 to 6 inches in diameter and 8 to 12 feet long (e.g., plastic drain pipe). The pipe should be capped at one end with a fine screen and supported in a vertical or near vertical position. A pail of polluted water should be positioned above the pipe and siphoned into it. The siphon tube can be clamped so that the water enters at a rate less than the permeability rate of the sand. In a few days, the water should begin to trickle out of the lower end of the tube. This water can then be observed and tested for purity.

VIII-A-3b: WATER PURIFICATION

QUESTION:

What is man's effect on the earth's water.

INTRODUCTION:

Man's population and water needs are both increasing. At the same time, he is continuing to pollute more of the hydrosphere. This set of conditions can only result in an eventual shortage of natural pure water. Because of this, more attention is being given to techniques of water purification.

The cost of purifying fresh (not waste) water ranges from a few pennies to seldom more than about twenty-five cents per thousand gallons. For purifying waste water, the cost will usually be greater, possibly as much as double.

The responsibility for designing and operating a water purifying plant is usually given to the chemist or chemical engineer. What are some ways in which waste water can be purified?

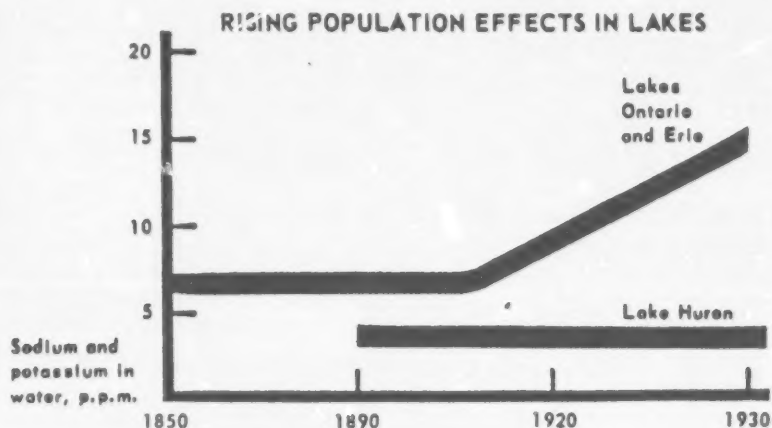
METHOD:

1. Place some muddy water in a beaker. Allow a few minutes for the heavy particles to settle to the bottom, then pour the partially settled water into another beaker.
2. To be sure that the water is sufficiently alkaline, dissolve a small amount of sodium bicarbonate in it.
3. Next, dissolve a small amount of aluminum sulfate in the water. (This can be accomplished by scraping the edge of a styptic pencil (which contains aluminum sulfate) with a sharp knife.)
4. Stir the mixture rapidly at first, to assure quick dispersion; then slowly, as a change begins to occur.
5. After stirring for 2 or 3 minutes, allow the mixture to stand.
6. Make careful visual observations of the changes that occur in the beaker, and record them.

QUESTIONS:

1. What change occurred in the beaker after the aluminum sulfate was added?

2. How does this change "purify" the water?
 3. After the change has occurred, is the remaining water "pure"?
- (A-3.21) 4. What are the characteristics of the pollutant that was removed from the water in this investigation?
- (A-3.32) 5.



- a) Which of the lake regions represented in the graph above would you expect to be most heavily populated? Explain.
 - b) On which of the lakes would you expect to find the greatest amount of industry? Explain.
 - c) What are some possible interpretations for the change in the graph of Lakes Ontario and Erie?
- (A-3.42) 6. Assuming that each person uses about 100 gallons of water per day and the approximate cost of purifying water is twenty-five cents per thousand gallons, what is the annual cost to purify water for use by you as an individual and by your community?

VIII-B-1a: THE LOCAL WATER BUDGET

QUESTION:

How is the water budget influenced by the environment?

MATERIALS:

Student handout sheet (Supplementary Sheet), three copies for each student.

SUGGESTED APPROACH:

1. Hold a class discussion during which the terminology used can be explained as the need arises. Use the blackboard or overhead projector and work through the Alexandria, Louisiana Water Budget table with the students participating. It is best not to have it prepared on the board before class, but fill it in with student help. Prepare a water budget graph for Alexandria, Louisiana. Have students fill in their own table and graph on their lab handout sheets while you or a student fills in the one on the board.
2. The remainder of the handout sheets can be completed as a homework assignment.
3. When the assignment is completed, conduct a class discussion including the following topics:
 - a) Hydrologic cycle, how it works.
 - b) Factors that determine which will occur, infiltration or surface runoff.
 - c) Factors that determine whether infiltrating water will stay in the rooting zone as stored capillary water or will continue downward to the water table.
Note: For more information, refer to Background Information.
 - d) How climate characteristics can be inferred from observations of water budgets.

PRECAUTIONS:

1. Students tend to get so involved in finding the right answer to the bookkeeping problems that they lose sight of the real purpose of the lab.
2. Students tend to conclude that soil saturation alone controls runoff.
3. This investigation should be completed before doing the stream hydrograph investigation.

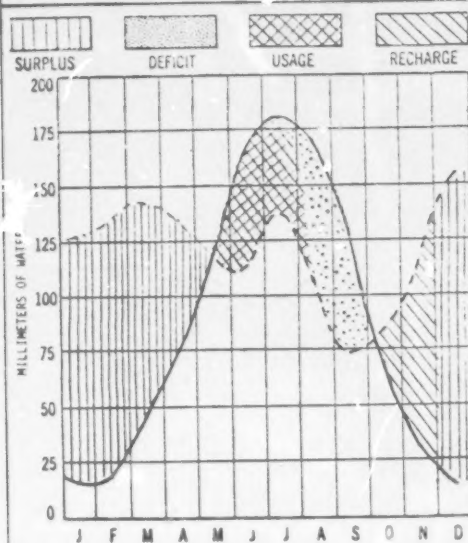
TYPICAL RESULTS:

1. Many students will falter with the bookkeeping and graphing the first time through. Continue to work with them until they understand that the bookkeeping and graphing are only mechanisms which will help them understand the water income, storage, and outgo relationship in a particular area. Eventually, most of the students should recognize this. Concentrate on their understanding of this relationship, and the arithmetic should eventually make more sense to them.
2. See diagrams on next sheet for typical results of the three areas investigated.

WATER BUDGET

FOR: Alexandria, Louisiana

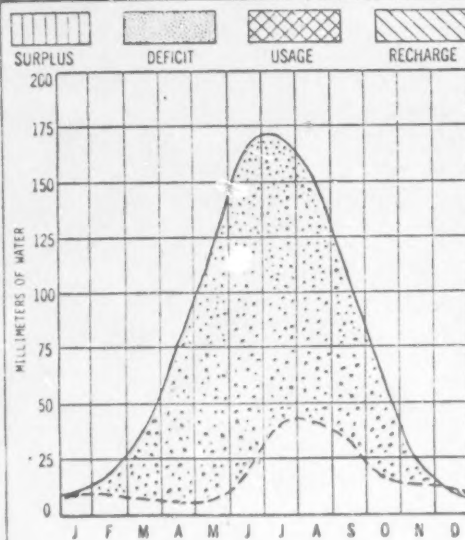
	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	127	133	142	134	119	115	133	106	73	85	111	152	1433
Ep	15	18	45	75	122	164	179	170	127	69	31	15	1032
P-Ep	112	115	97	59	-3	-49	-43	-64	-56	16	80	137	
ΔSb	0	0	0	0	-3	-49	-43	-5	0	16	80	4	
St	100	100	100	100	97	48	5	0	16	96	100		
Ea	15	18	45	75	122	164	179	111	73	69	31	15	917
D	0	0	0	0	0	0	0	59	56	0	0	0	115
S	112	115	97	59	0	0	0	0	0	0	0	133	516



WATER BUDGET

FOR: El Paso, Texas

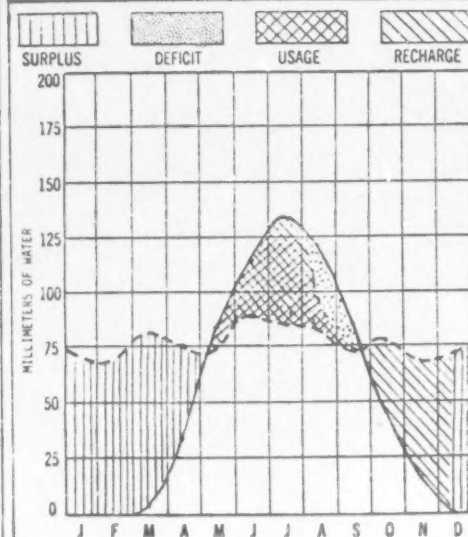
	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	10	11	8	7	8	18	40	41	33	17	13	12	210
Ep	11	18	27	75	117	163	171	152	111	62	24	10	451
P-Ep	-1	-7	-29	-68	-109	-145	-131	-111	-78	-45	-11	2	
ΔSb	-1	-1	0	0	0	0	0	0	0	0	0	2	
St	1	0	0	0	0	0	0	0	0	0	0	2	
Ea	11	12	8	7	8	18	40	41	33	17	13	10	218
D	0	6	29	68	109	145	131	111	78	45	11	0	733
S	0	0	0	0	0	0	0	0	0	0	0	0	0



WATER BUDGET

FOR: Syracuse, N. Y.

	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	72	68	61	75	74	67	66	62	72	70	63	52	911
Ep	0	0	3	34	53	115	144	122	74	46	15	0	636
P-Ep	72	68	58	41	-9	-28	-50	-40	-12	24	48	52	
ΔSb	0	0	0	0	-9	-28	-50	-13	0	24	48	17	
St	100	100	100	100	91	63	13	0	0	30	43	100	
Ea	0	0	3	34	53	115	144	75	72	46	15	0	547
D	0	0	0	0	0	0	0	27	12	0	0	0	39
S	72	68	58	41	0	0	0	0	0	0	55	314	



MODIFICATIONS:

Water budgets are available for most areas in New York State. The teacher may want to include more local data, either in place of or in addition to the data given in this lab.

BACKGROUND INFORMATION:

1. The hydrologic cycle operates like a pumping system with solar energy and gravity acting as the driving force. The water comes to the earth from the atmosphere as precipitation and condensation, from the earth to the atmosphere as evaporation and transpiration.
2. Not all the water on the earth is in motion. At any given moment, only about 5 gallons of every 100,000 is in motion. The rest is stored in the oceans, glaciers, underground water, and surface water.
3. Areas having excess solar energy (dry areas) will evaporate most of the precipitation arriving in the area.
4. Areas having excess precipitation (moist areas) will not evaporate all the precipitation arriving. The excess precipitation will either leave the area as surface runoff, be stored as capillary water within the rooting zone of plants, or penetrate through to the water table.

Factors determining which will occur, infiltration or surface runoff.

- A. Texture and structure of the soil - porosity and permeability.
- B. Thickness of the soil and water-absorbing characteristics of the bedrock underlying the soil.
- C. Slope of the land - steep slopes promote runoff; flat land promotes infiltration.
- D. Vegetative cover - vegetation decreases the velocity of raindrops and helps preserve the structure of the soil.
- E. Rate of precipitation - if the rate of precipitation exceeds the permeability rate of the soil, the surface zone will become saturated, encouraging runoff. (Relate this to Lab VIII-A-1a Water Movement Through Soils.)
5. Water that infiltrates into the soil may remain above the water table and within the root zone of plants as "capillary water," or it may continue to move downward as "gravity water" until it reaches the water table. This will depend on the dryness of the soil. The drier the soil, the more water will be retained as capillary water. After the soil reaches a certain moisture content, the remainder of the infiltrating water will continue to move downward under the influence of gravity until it reaches the water table, or saturated zone.

Note: Water budget computations consider only the "capillary water" stored above the water table and within the rooting zone of plants (this can extend downward from the surface 0-10 meters or more). Infiltrating water which passes through this zone and on to the water table is handled under the heading of surplus, since much of the excess will eventually seep back into stream beds and leave the area.

REFERENCES:

Investigating the Earth, pp. 218-223; Teacher's Guide, pp. 267, 273.
The Earth Sciences, A. N. Strahler, Chapter 25.

VIII-B-1a: THE LOCAL WATER BUDGET

QUESTION:

How is the water budget influenced by the environment?

INTRODUCTION:

What happens to the precipitation and condensation that reaches the earth's surface? If we were to investigate this question in a local area, we would find that some water escapes from the region in stream flow, some evaporates or is transpired by plants, and some sinks into the ground.

This information may be summarized in the following equation: Precipitation = evapotranspiration + stream flow + infiltration, or in symbols:

$$P = E_a + S.F. + I.$$

In a local area drained by one stream, we could measure some of these variables. The total precipitation can be measured by using rain gauges placed randomly throughout the area. The stream flow can be measured by determining the volume of water passing through the stream channel at a point where it leaves the area. Infiltration can be determined by observing water level changes in dug wells where the porosity of the soil is known.

Evapotranspiration is not as easily measured because of interaction between variables such as: wind velocity, relative humidity, temperature, and various types of vegetation, each with a different transpiration rate. However, by rearranging the above equation to $E_a = P - S.F. - I$, we can solve for E_a .

This method is sometimes used to determine the input - output relationship of water in an area. Because of the expense involved in carrying out a prolonged investigation of this type, it is seldom done unless warranted by major projects such as vast irrigation systems, dam building, etc.

The water budget is a model which can be used to analyze the changes that occur within an area. The model is an approximation for a general area and does not always represent specific conditions at all points within the region.

The values that are derived in the table will help you determine probable periods of water runoff and water storage.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. when given the Ep and P data for a locality and the maximum soil storage in mm. of water, you should be able to:
 - a) identify the climate as being moist or dry.
 - b) identify months when maximum surface runoff will likely occur (flood potential).
 - c) identify months when soil moisture storage is at a minimum and irrigation may be desirable.
 - d) identify periods of soil moisture usage and recharge.

METHOD:

1. Complete the water budget table for Alexandria, Louisiana, and prepare a water budget graph.
2. Prepare a water budget graph for Syracuse, New York and El Paso, Texas.

On each of the water budget graphs, label the following, if present:

- A. USAGE - months when stored moisture was withdrawn from the plant rooting zone of the soil by plants and evaporation.
- B. RECHARGE - months when the stored moisture within the rooting zone of plants was replenished.
- C. SURPLUS - months when storage within the rooting zone was at a maximum (100 mm.) and surface runoff or penetration through to the water table occurred.
- D. DEFICIT - months when solar energy is available to withdraw moisture but none is available either in the rooting zone moisture or as fresh precipitation.

QUESTIONS:

- (B-1.11) 1. What is the moisture source for a water budget?
- (B-1.21) 2. What factors determine the maximum evapotranspiration that can occur in an area?
- (B-1.31) 3. What was assumed to be the maximum amount of water that could be stored within the rooting zone of plants as capillary water?

- (B-1.41) 4. When precipitation is less than potential evapotranspiration, what is likely to happen to soil moisture storage?
- (B-1.51) 5. When does a moisture deficit exist?
- (B-1.61) 6. When precipitation is more than potential evapotranspiration, what will happen to soil moisture storage?
- (B-1.71) 7. What are the conditions under which surplus moisture may exist?
- (A-2.11) 8. What are some surface or near surface soil conditions that might lead to surface runoff?
 - 9. Which climate is most desert-like, El Paso or Alexandria?
 - 10. How does the climate of Syracuse compare to El Paso and Alexandria?
 - 11. Why are the E_p values high in the summer and low in the winter?
- (C-1.11) 12. What factor probably accounts for the similarity between the E_a curves of El Paso and Alexandria and the dissimilarity of the E_a curve for Syracuse?
- 13. How does the water budget of an area where freezing winter temperatures are experienced differ from water budgets of an area where the temperature remains above freezing all year?

SUPPLEMENTARY SHEET

VIII-B-1a

(Water Budget Table & Graph)

Alexandria,
Louisiana

	J	F	M	A	M	J	J	A	S	O	N	D
P	127	133	142	134	119	115	136	106	73	85	111	152
Ep	15	18	45	75	122	164	179	170	129	69	31	15

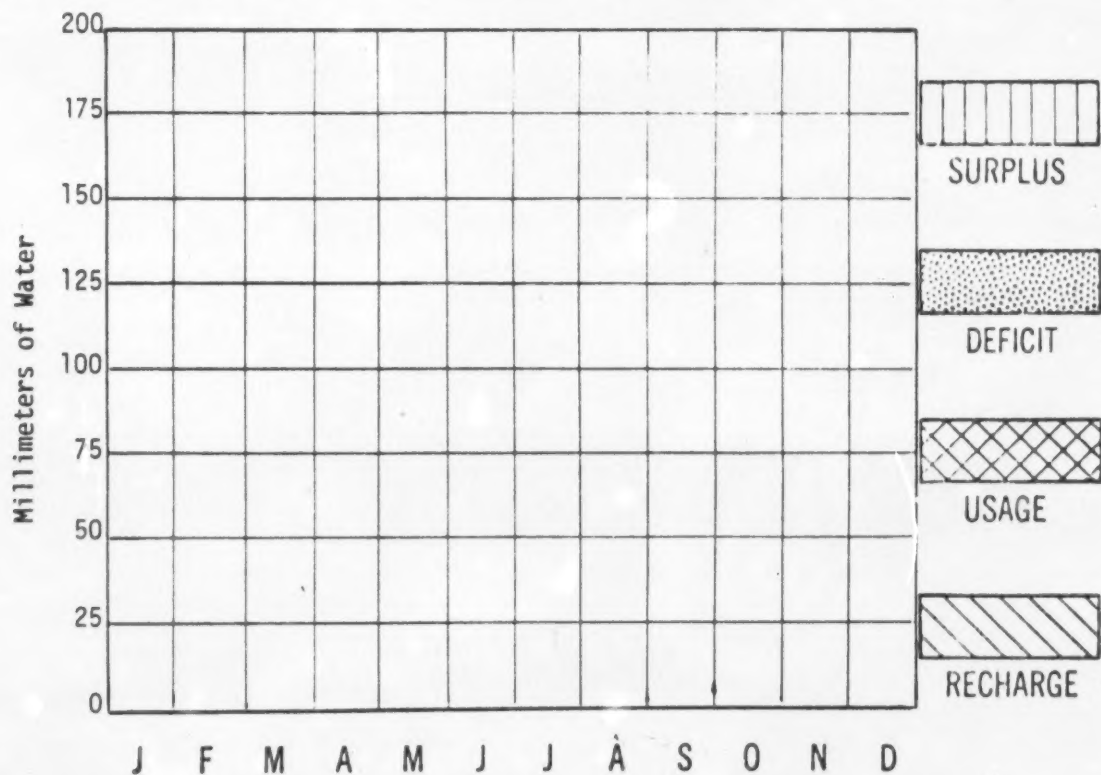
Syracuse,
N.Y.

	J	F	M	A	M	J	J	A	S	O	N	D
P	72	68	81	75	74	87	84	82	72	76	68	72
Ep	0	0	3	34	83	115	134	122	84	46	15	0

El Paso,
Texas

	J	F	M	A	M	J	J	A	S	O	N	D
P	10	11	8	7	8	18	40	41	33	17	13	12
Ep	11	18	37	75	117	163	171	152	111	62	24	10

	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P													
Ep													
P-Ep													
ΔSt													
St													
EA													
D													
S													



VIII-B-2a: STREAM HYDROGRAPHS

QUESTION:

How is the local water budget related to stream discharge?

MATERIALS:

1. Tables of daily streamflow measurements for: Horsepen Creek, Harbor Brook, and Government ditch (supplementary sheets).
2. Completed copies of the local water budget investigation.

SUGGESTED APPROACH:

1. Review concepts of the water budget with the students. Place emphasis on conditions that result in surface runoff. Ask the students how information concerning runoff from an area could be measured.
2. Have the students graph data (see precaution #2). This can be accomplished as a homework assignment, providing a uniform graphing scale is agreed upon.
3. When the assignment is completed, have the students connect their sections of the graphs. Display the three completed graphs on the wall. Ask the students to observe and compare the stream hydrograph with the water budget from the same area and to defend their comparisons in each case.

PRECAUTIONS:

1. The water budget investigation should be completed before this investigation is begun.
2. Make the job of graphing brief. Expecting a student to graph an entire year by days, or even by weeks, is tedious. Have each student graph a small part, and then combine the parts for a large yearly graph. This way, many hydrographs can be easily completed.
3. Do not indicate the locations of these streams to the students until completion of the investigation.

BACKGROUND INFORMATION:

1. Horsepen Creek is located near Provencal, La. The measurement was made near the left bank on downstream side of bridge on State Highway 117, 3 1/2 miles south of Provencal. This location is approximately 50 miles NW. of Alexandria, Louisiana.
2. Harbor Brook is located near Syracuse, N.Y. The measurement was made on the right bank 145 feet downstream from bridge on Velasko Road at Syracuse, Onondaga County, and about 3 miles upstream from the mouth.
3. Government ditch is located near El Paso, Texas. The measurement was made at the intersection of Montana and Houston Streets, El Paso, Texas.

REFERENCES:

- Investigating the Earth*, pp. 204-225, Teacher's Guide, pp. 255-279.
Water Resources Data for Texas - 1968, Part I, Surface Water Records.
Water Resources Data for Louisiana - 1968, Part I, Surface Water Records.
Water Resources Data for New York - 1968, Part I, Surface Water Records. This catalog of streamflow data can be obtained from the District Chief, Water Resources Division, U. S. Geological Survey, P. O. Box 948, Federal Building, Albany, New York.

VIII-B-2a: STREAM HYDROGRAPHS

QUESTION:

How is the local water budget related to stream discharge?

INTRODUCTION:

What is the pattern of streamflow throughout a year? How is the change in volume of a stream related to the water budget? Would you expect a seasonal pattern to exist in streamflow? In this investigation, you will analyze streamflow data and compare it with the water budget from the area.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. identify the months during which maximum and minimum streamflow occurred when provided with a yearly hydrograph for a stream;
2. match a stream hydrograph of an area with a water budget from the same climatic region.

METHOD:

1. Graph the data provided in the manner explained by your teacher.
2. Compare your graph or graphs with the water budgets that are available to you.
3. The stream hydrographs you have prepared are for streams in the vicinity of each of the three water budget areas that you worked with in a previous lab. Observe the characteristics of both your water budgets and stream hydrographs, and attempt to match the hydrograph with the water budget area near which the stream is located.

QUESTIONS:

1. Compare the land area drained by each of these streams. Describe their sizes relative to some local streams with which you are familiar.
- (A-2.11) 2. What is the relationship between streamflow and precipitation? Will this relationship be more pronounced in a small stream or in a very large stream? What factors other than precipitation might affect the rate of increase of stream discharge?

- (A-3.31) 3. According to the "Remarks" concerning flow of Harbor Brook, what effect has man had on this stream? What density of human population would you expect to find near the gauging station in this stream.
- (B-2.11) 4. What could be the source of the water that keeps streams flowing even during long periods of no precipitation?
- (A-2.11) 5. What is the basis on which streamflow data can be matched with water budget data?

Horsepen Creek

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	.20	.43	.32	2.3	1.6	4.8	2.1	1.3	1.0	.32	.32	.80
2	.18	.32	.43	2.9	3.1	3.5	120	1.2	.92	2.1	.30	.80
3	.16	.30	.64	2.6	1.9	5.3	28	1.2	1.1	6.5	.30	1.1
4	.15	.24	.40	5.8	1.4	3.4	106	8.9	.96	1.1	.28	11
5	.14	.28	.32	31	1.1	2.9	32	2.8	.76	.61	.24	24
6	.14	.28	.32	44	.96	3.7	8.5	1.2	.88	.43	.22	11
7	.14	.28	.32	5.5	.88	3.4	4.2	1.1	1.1	.34	8.1	2.9
8	.16	.28	.32	3.0	.84	2.7	269	1.1	1.1	.30	20	1.4
9	.24	.28	.37	100	.88	2.5	280	2.9	.92	.30	1.4	1.2
10	.16	.28	.55	42	.88	2.4	48	119	.84	.34	5.5	1.1
11	.15	.26	.61	7.9	.88	9.5	21	42	.80	.32	108	1.1
12	.14	.26	.80	4.0	.84	19	14	31	.76	.32	159	1.0
13	.14	.28	.55	3.1	.84	4.4	12	9.3	.72	.37	105	.92
14	.14	.28	2.4	2.7	.88	3.0	9.7	4.5	.68	.37	21	.88
15	.13	.26	49	2.3	1.9	2.6	8.1	3.0	.64	.40	11	9.1
16	.43	.26	5.3	2.0	1.7	2.3	6.7	2.4	1.1	.37	7.5	5.8
17	.43	.28	8.9	1.9	1.3	2.0	6.0	48	.64	.37	5.7	6.0
18	.24	.26	3.8	1.7	1.3	1.9	5.3	79	.52	.52	4.7	4.4
19	.20	.28	1.3	1.6	1.3	1.7	4.8	9.3	.52	.80	3.3	1.2
20	.20	.30	.88	1.5	1.1	1.8	4.4	4.1	.49	.61	2.8	1.1
21	.20	.30	.80	1.4	1.1	6.7	5.1	2.9	.46	1.2	2.4	1.1
22	.20	.32	1.4	1.5	1.4	61	8.1	2.1	.52	11	2.0	1.0
23	.20	.34	.84	12	1.5	14	5.1	1.4	.76	112	1.6	.92
24	.18	.37	.64	7.1	1.6	5.3	4.0	1.2	.84	24	1.2	.88
25	.15	.32	.58	3.2	2.4	3.7	3.1	1.1	.92	6.0	1.2	.80
26	.15	.30	.52	2.3	1.6	3.0	2.8	16	6.3	1.8	1.1	.88
27	.15	.30	.55	1.8	1.2	2.7	2.6	4.4	1.2	1.1	1.1	.88
28	.15	.28	1.3	1.5	43	2.4	2.5	2.4	.68	.80	1.1	.76
29	.18	.30	.92	1.4	16	2.3	3.1	1.2	.49	.58	1.0	.72
30	2.6	.32	.80	1.3	----	2.1	2.5	1.1	.37	.52	.92	.68
31	.96	----	2.3	1.3	----	1.3	----	1.1	----	.40	.88	----
TOTAL	8.99	8.84	88.18	302.6	95.38	187.9	1,028.7	408.2	28.99	176.19	479.16	95.42

Drainage area.--5.27 sq. mi.

Remarks.--Records good.

Harbor Brook

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	6.1	3.1	7.1	7.1	22	5.5	26	5.7	5.0	18	5.5	3.7
2	5.5	48	6.4	6.8	40	5.5	16	5.5	4.8	15	5.1	3.8
3	5.5	24	11	6.4	25	5.4	14	5.7	4.7	13	5.0	3.7
4	4.7	12	7.7	6.1	18	5.4	19	5.5	4.5	11	4.7	3.7
5	4.3	9.0	7.1	6.1	17	5.4	17	5.2	4.5	12	5.0	3.8
6	4.2	6.8	6.8	5.8	15	5.4	14	5.2	4.5	14	5.8	5.1
7	4.1	5.5	6.8	5.8	14	5.2	13	5.1	4.4	11	9.3	3.9
8	4.3	5.2	7.4	5.7	13	5.8	13	5.1	4.0	10	4.7	3.6
9	4.5	5.1	6.4	5.5	13	8.0	11	5.2	4.4	20	4.8	3.6
10	3.8	5.2	6.1	5.4	12	13	11	6.4	4.4	28	4.7	4.7
11	3.1	5.1	13	5.1	11	22	10	5.2	4.3	11	4.5	14
12	3.1	8.1	23	4.7	11	8.4	9.8	6.8	6.1	10	4.3	5.0
13	3.1	12	14	4.5	11	5.0	9.0	5.5	4.7	9.0	4.3	4.0
14	3.2	8.4	11	4.5	10	4.3	8.7	5.2	4.4	8.4	4.1	3.9
15	3.2	7.1	8.7	5.2	10	5.2	9.0	5.0	4.7	8.0	4.0	3.9
16	3.4	6.8	8.0	5.1	9.8	18	8.0	5.7	4.4	7.4	4.2	3.8
17	3.6	6.1	7.7	5.1	9.4	44	7.4	5.2	4.4	7.4	4.1	3.8
18	7.0	14	17	5.2	9.0	21	8.0	5.7	4.2	71.	4.0	3.7
19	14	17	26	5.7	7.4	26	6.8	6.8	4.1	6.8	4.1	3.7
20	4.8	11	15	5.5	7.1	19	6.8	8.4	3.9	6.8	4.0	3.6
21	3.5	9.4	13	5.4	6.8	14	6.8	5.5	3.8	6.4	3.9	3.5
22	3.3	13	12	5.2	6.1	37	11	5.0	4.3	6.4	19	3.7
23	3.3	43	10	5.2	5.8	38	7.4	4.8	3.7	6.1	5.5	3.6
24	3.2	19	9.4	4.7	5.5	23	7.4	4.7	4.7	7.4	4.5	3.6
25	14	15	8.7	4.3	5.0	22	6.4	4.5	4.8	6.8	5.0	3.5
26	10	14	8.4	4.2	4.8	29	6.1	4.4	99	7.1	4.1	3.5
27	3.8	11	7.7	4.4	5.2	26	8.0	4.4	30	7.1	3.9	3.5
28	3.5	9.4	7.7	4.8	5.4	19	5.8	4.4	39	7.4	3.8	3.5
29	3.3	8.4	7.7	9.4	5.5	17	5.7	6.8	21	6.1	3.8	3.4
30	3.2	7.7	7.4	53	----	15	6.8	8.0	19	6.1	3.8	3.4
31	3.2	----	7.1	25	----	15	----	5.7	----	6.1	3.8	----
TOTAL	149.8	369.4	315.3	236.9	334.8	492.5	308.9	172.3	320.1	306.9	157.3	124.2

Drainage area.--9.63 sq. mi.

Remarks.--Records fair. Flow includes some sewage and storm sewer inflow, some originating outside the basin.

Government ditch

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0	0	0	0	0	0	0	0	0	0	6.2	.06
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	.01	0	0	0	0	0	0	1.2	0	0
4	0	0	.01	0	0	0	0	0	0	8.0	0	0
5	0	0	0	0	0	0	0	0	0	17	1.6	0
6	0	0	0	0	0	0	0	0	.05	46	2.6	0
7	0	0	0	.02	.03	0	0	0	0	0	.58	0
8	0	0	0	.07	0	3.6	0	0	0	0	0	0
9	0	0	0	0	0	.84	0	0	0	0	0	0
10	0	0	0	0	.10	1.5	0	0	0	0	0	.05
11	0	0	0	0	0	.83	.06	0	0	0	0	0
12	0	0	0	0	1.8	0	0	0	0	0	0	0
13	0	0	0	0	1.1	0	0	0	0	0	.03	0
14	0	0	.02	0	.53	0	0	0	0	0	.05	0
15	0	0	.01	0	0	0	0	0	0	0	0	0
16	0	0	.26	0	0	0	0	0	0	0	0	0
17	0	0	.41	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	.05	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	.21	0
23	0	0	0	0	0	0	0	0	0	.21	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	.07	0	0	0	0	0	0	0	0	0	0
27	0	.06	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	.87	0	0	0	0	0	.05	0
29	0	0	0	0	0	0	0	0	0	.01	.07	0
30	.11	0	0	0	----	0	0	0	0	0	0	0
31	0	----	0	0	----	0	----	0	----	5.3	0	----
TOTAL	0.11	0.13	0.72	0.14	4.43	6.77	0.06	0	0.05	77.72	11.39	0.11

Drainage area.--6.4 sq. mi., approximately.

Remarks.--Records good.

VIII-C-1a: CLIMATE OF AN IMAGINARY CONTINENT

QUESTION:

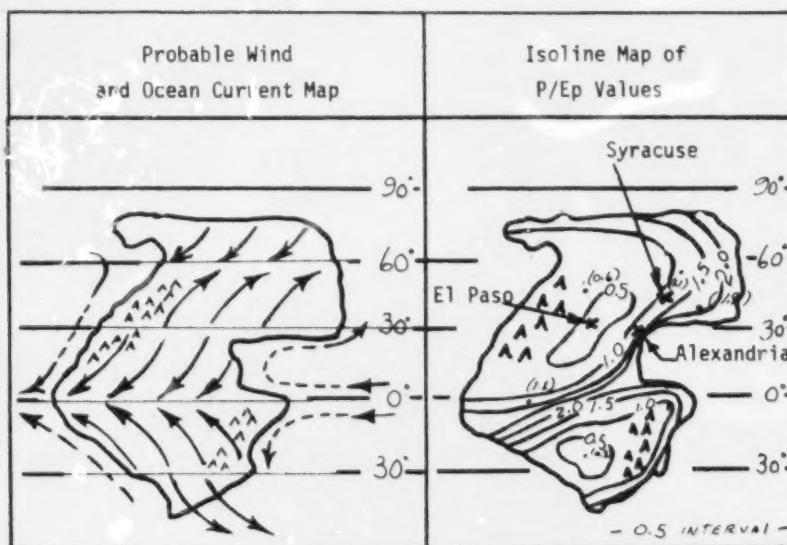
What factors affect climate patterns?

MATERIALS:

Student handout sheets including the supplementary sheet (map of an imaginary continent), completed water budget investigations, colored pencils or crayons, and optional photographs (magazine or 35 mm. slides) taken in various world climate areas.

SUGGESTED APPROACH:

- Part I A. Ask the students what kinds of relationships between precipitation and potential evapotranspiration they would expect to find in an arid region, and in a humid region. Could this relationship be expressed numerically as a ratio? What range of numbers would represent arid regions? humid regions?
- B. Have the students prepare a P/Ep isoline map from the information plotted on the map of the imaginary continent. Have them shade arid regions in red and humid regions in blue. This can best be done as a homework assignment.
- Part II A. When part I has been completed, briefly discuss the P/Ep isoline map making certain that all students have identified the major arid and humid regions.
- B. Ask the students if they could improve upon their maps by designating more accurate climatic regions, such as humid, subhumid, semiarid, arid, and mountain climate zones if they were to consider other factors (i.e., latitude, elevation, nearness to large bodies of water, ocean currents, mountain barriers, and planetary wind systems). In a class discussion, decide on the probable ocean current patterns and planetary wind systems that might be found on and around the imaginary continent (see map under Typical Results).
- Allow the students to complete refinements on their maps as a homework assignment.
- Part III As a concluding class exercise, have the students refer to their water budget investigation and plot on the imaginary continent the most likely position for each of the three water budget locations. Have them study photographs, either projected on a screen or in magazines, taken in various world climatic regions and match these with their most probable location on the imaginary continent (see map under Typical Results).

TYPICAL RESULTS:BACKGROUND INFORMATION:

P/Ep Ratio	Climatic Type	Generalized Type
Greater than 1.2	Humid	Humid
0.8 - 1.2	Subhumid	
0.4 - 0.8	Semiarid	Arid
Less than 0.4	Arid	

REFERENCE:

- Investigating the Earth*, pp. 247-266; Teacher's Guide, pp. 299-327.
The Earth Sciences, Strahler, ch. 18.
Earth Science, The World We Live In, Namowitz and Stone, ch. 41 & 42.
Principles of Climatology, Neiberger and Cahir, Holt, Rinehart and Winston, 1969.

VIII-C-1a: CLIMATE OF AN IMAGINARY CONTINENT

QUESTION:

What factors affect climate patterns?

INTRODUCTION:

You are well aware that many areas of the world have unusual climates - deserts, tropical rain forests, polar ice caps, etc. What causes these differences? Are they predictable, knowing certain information? In this investigation, you will apply what you have learned about water budgets to locations on a continent to help answer these questions.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. identify arid and humid regions when given yearly precipitation and potential evapotranspiration data for various points within an area.
2. outline climatic zones based on P & Ep data, latitude, elevation, nearness to large bodies of water, ocean currents, and planetary wind system information for an imaginary continent.
3. match a set of water budget graphs with their most probable location on an imaginary continent.
4. match a series of photographs taken in various world climatic regions with their most likely position on an imaginary continent.

METHOD:

- Part I On the outline map containing P/Ep ratio data for a number of locations within an imaginary continent, construct iso-P/Ep lines. When the lines are completed, color the humid regions blue and the arid regions red.
- Part II A. Defend your classification of these regions in a class discussion and be prepared to outline other factors that would enable you to identify a more elaborate classification system.
- B. As a result of your class discussion, outline as complete a climatic classification system as you are able, on a new imaginary continent map.
- Part III A. Match the three localities for which water budget information was completed, in an earlier investigation, with their

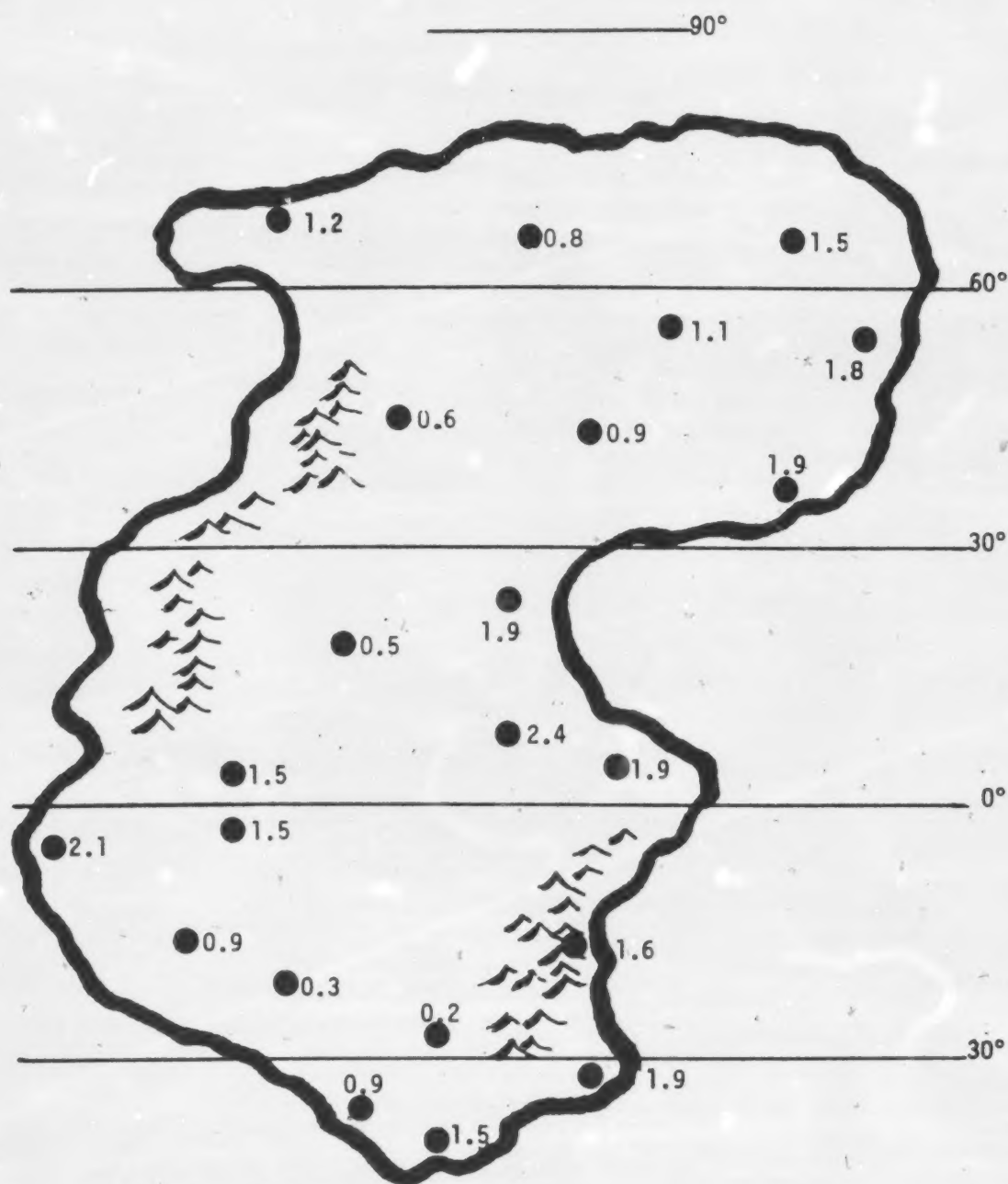
probable position on your completed climate map of the imaginary continent. Be prepared to defend your decision.

- B. Match a series of photographs taken in various world climatic regions with their most likely position on your imaginary climate.

QUESTIONS:

- (B-3.11) 1. How can precipitation and potential evapotranspiration data be used to identify climatic regions?
- (C-1.11) 2. What relationship exists between latitude and climatic patterns?
- (C-1.21) 3. Describe the effect of elevation on climatic patterns?
- (C-1.31) 4. What effect does a large body of water have on the climate of a nearby landmass?
- (C-1.32) 5. What effect does an ocean current have on the climate of a nearby landmass?
- (C-1.41) 6. How do mountains affect the climate of a region?
- (C-1.51) 7. How do planetary wind and pressure belts affect climate?

MAP OF AN IMAGINARY CONTINENT



Adapted from:

Investigating the Earth, Teacher's Guide.